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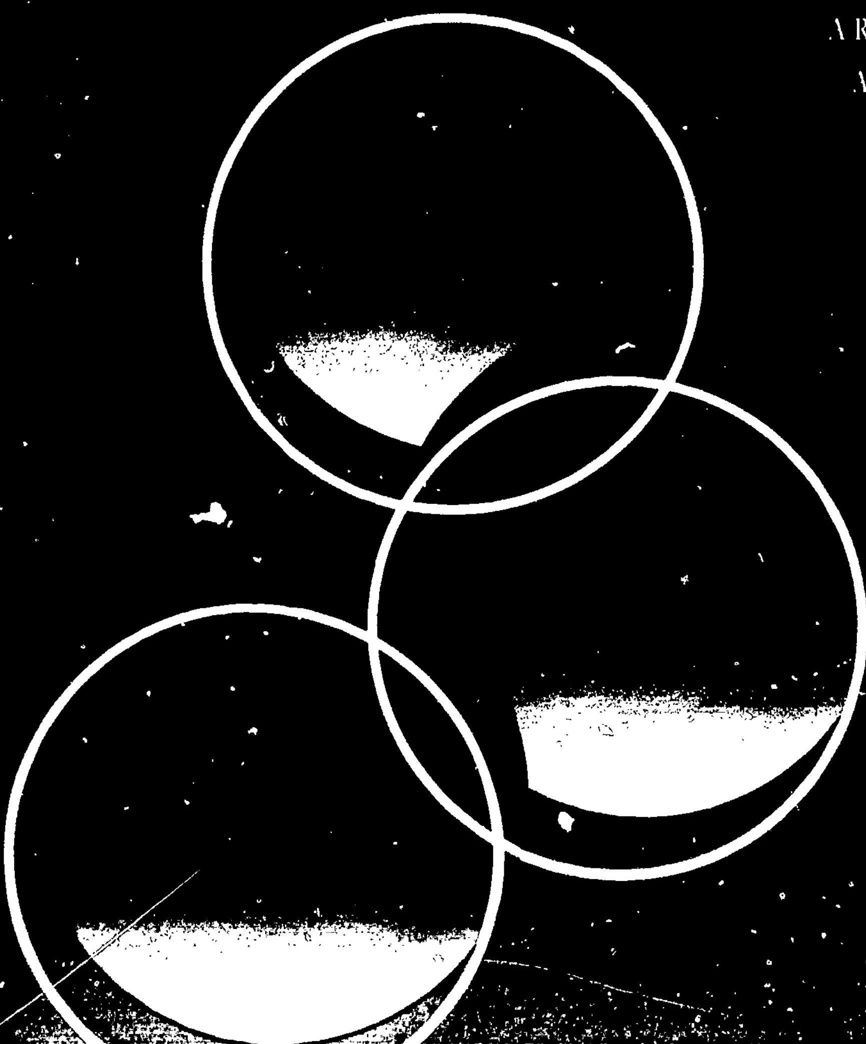
ABSTRACT

In an effort to explore critical issues important to the development of high quality science and engineering technicians, 115 technicians, technician educators, government representatives, and employer gathered in July 1993 to provide recommendations for future activities and projects designed to improve the quality of the U.S. technician workforce. This document provides a discussion of workshop activities. Included are: (1) a brief summary of the state of technician workforce; (2) workshop reports which includes "Professionalism of Technician Careers," "Alliances," "Faculty," "Human Resources Issues--Recruitment, Retention, and Placement," "Curriculum and Program Development," and "Secondary School Education for Technical Careers"; (3) sections on issues and recommendations for each workshop report topics; and (4) implications for policy. Also included are abstracts from selected preconference papers and the following articles: (1) "What Do Technicians Do?" by Stephen R. Barley; (2) "Education for Engineering and Industrial Technicians in the Reinvestment Economy" by Lawrence J. Wolf; (3) "One Society's Response to Technician Needs" by Kenneth M. Chapman; and (4) "Critical Issues in Science and Engineering Technician Education Invitational Workshop, Summary Comments" by George R. Boggs. (ZWH)

GAINING THE COMPETITIVE EDGE:

CRITICAL ISSUES IN SCIENCE AND ENGINEERING TECHNICIAN EDUCATION

A REPORT FROM
A WORKSHOP
SPONSORED BY THE
NATIONAL SCIENCE FOUNDATION
AND THE
FEDERAL COORDINATING
COUNCIL
FOR SCIENCE,
ENGINEERING, AND
TECHNOLOGY



Division of Undergraduate Education
Directorate for Education and Human Resources
National Science Foundation
July 1993

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The opinions expressed in this report are those of the workshop participants and do not necessarily represent NSF policy. Their recommendations are under review at NSF.

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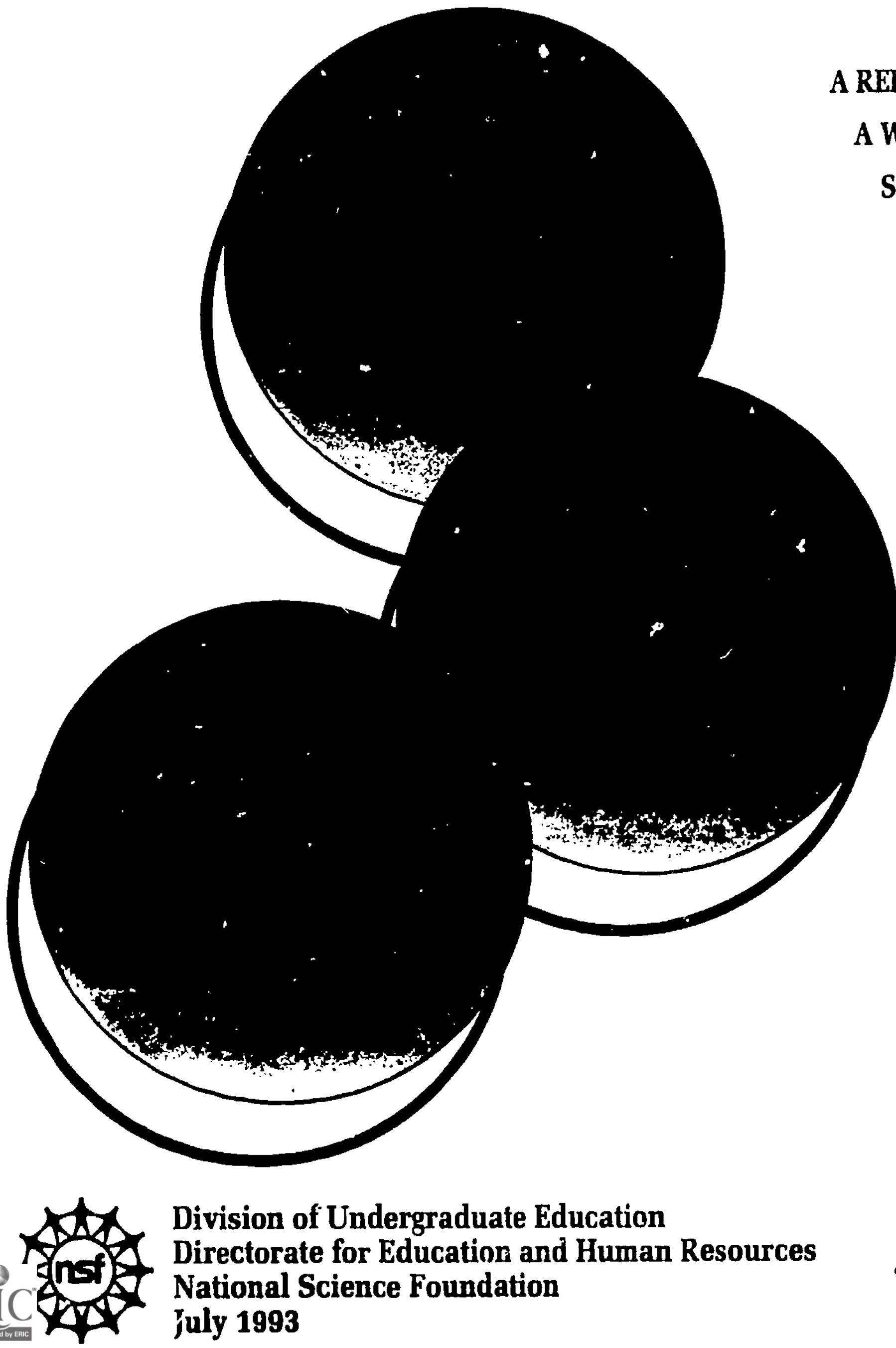
GAINING THE COMPETITIVE EDGE:

CRITICAL ISSUES IN SCIENCE AND ENGINEERING TECHNICIAN EDUCATION



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Timothy W. Collins
Don K. Gentry
Vernon O. Crawley
Co-Chairs
July 20-23, 1993

Division of Undergraduate Education
Directorate for Education and Human Resources
National Science Foundation
July 1993

NATIONAL SCIENCE FOUNDATION
DIRECTORATE FOR EDUCATION AND HUMAN RESOURCES

February 1, 1994

Dr. Neal F. Lane
Director
National Science Foundation
4201 Wilson Boulevard
Arlington, Virginia 22230

Dear Neal:

I am pleased to submit the report from the workshop on critical issues in science and engineering technician education that was a joint effort of the National Science Foundation and the Federal Coordinating Council for Science, Engineering, and Technology. The workshop was developed with leadership from the Division of Undergraduate Education and with significant support from the Division of Elementary, Secondary, and Informal Education and other divisions of the Directorate for Education and Human Resources. The American Chemical Society and the American Society for Engineering Education provided additional leadership and information to ensure that issues were addressed by representatives from all groups who are stakeholders in science and engineering technician education and professional development.

On July 21-23, 1993, 115 technicians, technician educators, government representatives, and employers met to explore issues important to the development of high quality science and engineering technicians in the United States. During the three days, participants worked in interdisciplinary groups to develop recommendations that provide a basis for future activities and projects designed to improve the quality of the U.S. technician workforce. Through their joint efforts, and with expanded support from NSF and others, academia and employers can work together to significantly improve the technical workforce. Recommendations of the workshop are being carefully considered. Many of the perspectives gained from participants were immediately incorporated into NSF's *Advanced Technological Education* program which received final approval on August 19, 1993.

Sincerely,

Luther S. Williams

Luther S. Williams
Assistant Director

LETTER OF TRANSMITTAL

January 24, 1994

Dr. Robert F. Watson
Director
Division of Undergraduate Education
National Science Foundation
4201 Wilson Boulevard
Arlington, Virginia 22230

Dear Dr. Watson:

We are pleased to forward to you the report of the FCCSET workshop, *Gaining the Competitive Edge: Critical Issues in Science and Engineering Technician Education.* We thank you for the leadership and support provided by the Division of Undergraduate Education at NSF in the workshop. We recognize that this was one of the major activities in 1993 of FCCSET CEHR-CIT Joint Working Group on Technical Education and the FCCSET Working Group on Undergraduate Education. We are especially appreciative for the support in this major undertaking from Luther S. Williams, Chair of FCCSET and Assistant Director for Education and Human Resources (EHR) at NSF.

This workshop, held July 21-23, 1993, focused on strategies to help develop a high quality science and engineering technician workforce in the United States; provide recognition of the importance of highly educated technicians to the national economy; and initiate greater cooperation on education of technicians between academe and industry. The 115 participants represented high technology companies, two-year colleges, four-year colleges and universities, secondary schools, professional societies, and federal agencies with interest in the education of technicians.

With the assistance of the planning committee and NSF staff, participants received assignments prior to the workshop designed to stimulate their thinking on six critical issues. Each of the following six topics was addressed by an interdisciplinary working group:

- professionalism of technician careers;
- alliances for technician workforce development;

- faculty development and enhancement;
- human resources issues including recruitment, retention, and placement of students;
- curriculum and program development and improvement; and
- secondary school education of candidates for advanced technician careers.

This report has been reviewed by members of the planning committee, the chairs and recorders of the working groups, and all other participants. We now submit it to NSF in the spirit of cooperation, collaboration, and mutual optimism for the future of technician education and careers in the United States. We encourage NSF, in cooperation with other federal agencies and business, industry, government, and academia, to take a leadership role in implementing the recommendations in the report. An excellent beginning has been made with the creation of the *Advanced Technological Education* (ATE) program and the expansion of other programs at the Foundation.

On behalf of all participants of the workshop, we wish to extend to Elizabeth Teles of the Division of Undergraduate Education at NSF and Kenneth Chapman of the American Chemical Society, our deepest appreciation for their leadership role in this endeavor. Your continued commitment to technician education and your recognition of the central role of two-year colleges is applauded by both the education and employer communities.

Sincerely,

Timothy W. Collins
Workshop Co-Chair
The Procter and Gamble Company

Vernon O. Crawley
Workshop Co-Chair
Moraine Valley Community College

Don K. Gentry
Workshop Co-Chair
Purdue University

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Foreword

This FCCSET workshop, *Gaining the Competitive Edge: Critical Issues in Science and Engineering Technician Education,* was a natural extension of recent workshops, studies, and reports supported by the National Science Foundation (NSF) to help improve science, technology, engineering and mathematics education in the United States. The 1986 National Science Board report, *Undergraduate Science, Mathematics, and Engineering Education* (NSB 86-100), identified serious problems in undergraduate education and included recommendations for improving the quality of science, mathematics, and engineering programs in two-year colleges. NSF then convened a workshop that resulted in the report, *NSF Workshop on Science, Engineering, and Mathematics Education in Two-Year Colleges* (NSF 89-50). A variety of groups then undertook studies that served as resources for a subsequent NSF workshop that produced the report, *Matching Actions and Challenges* (NSF 91-111). This report contained specific recommendations for two-year college faculty, professional organizations, and college administrators to foster improved interactions among organizations, faculty, and federal funding agencies.

To provide a base for future activities and projects designed to improve science, technology, engineering, and mathematics education in two-year colleges by utilizing the resources and networking available from professional societies, NSF convened a workshop, *Partners in Progress,* on October 29-30, 1992. The report from this workshop, *Partners in Progress* (NSF 93-64), noted that the educational community [all types of colleges and professional societies] can improve the quality and effectiveness of science, technology, engineering, and mathematics education at all levels to help the nation remain a leader in the world marketplace and meet the challenges of the future (p. 3).

The present workshop was in response to a nationally recognized need for a well-educated technical workforce in the high performance work place of advanced technologies. Both Congress and the White House emphasized the technical workforce in their 1992 and 1993 initiatives. Congress passed and the Administration supported the *Scientific and Advanced Technology Act of 1992* which called for the National Science Foundation to establish a national program to improve the education for technicians in advanced technology fields utilizing the resources of the nation's two-year colleges. In August, 1993, NSF announced the *Advanced Technological Education* (ATE) program as a cooperative effort between the Division of Undergraduate Education and the Division of Elementary, Secondary, and Informal Education. These efforts have created a sound foundation for cultivating innovative programs to advance technician education in the United States.

With the experience of several recent workshops that addressed science, engineering, and mathematics education in institutions that traditionally educate technicians, NSF supported the proposal of the American Chemical Society (ACS) for an invitational workshop to address science and engineering technician education in depth. The American Society for Engineering Education (ASEE), the Joint Working Group on Technology Education of FCCSET, and the FCCSET Working Group on Undergraduate Education joined ACS and NSF as co-sponsors of the workshop. The 115 participants who attended represented high technology companies, two-year colleges, four-year colleges and universities, secondary schools, professional societies, and federal agencies with interest in the education of technicians.

Over the three day period, participants worked to develop recommendations that provide a basis for future activities, initiatives, and projects designed to improve technician education.

The opinions expressed in this report are those of the workshop participants and do not necessarily represent NSF policy. The recommendations are under review at NSF.

EXECUTIVE SUMMARY

The workshop, *Gaining the Competitive Edge: Critical Issues in Science and Engineering Technician Education*, addressed issues relevant to ensuring the high quality of science and engineering technicians in the United States. The workshop was timely because it has become increasingly apparent that for the United States to maintain a competitive edge in the world market, while being environmentally concerned, the technical component of the workforce in the United States must be better prepared than the corresponding workforce in other industrialized countries. The purpose of the workshop was to identify critical issues in science and engineering technician education, to develop recommendations for industry, academe, and government; and to engage these communities into action. Deliberations focused on development of strategies to strengthen two-year college technician education programs; however, improving education programs for prospective technicians at the secondary school level and expanding opportunities for technicians at four-year colleges and universities and after their employment were addressed as well.

The 115 participants who attended the workshop, held July 21-23, 1993, represented high technology companies, two-year colleges, four-year colleges and universities, secondary schools, professional societies, and federal agencies with an interest in the education of technicians. The workshop was co-sponsored by the American Chemical Society (ACS), the American Society for Engineering Education (ASEE), the FCCSET CEHR-CIT Joint Working Group on Technical Education, the FCCSET Working Group on Undergraduate Education, and the National Science Foundation (NSF).

PRINCIPAL RECOMMENDATIONS

Participants were divided into six working groups to examine the following issues:

- professionalism of technician careers;
- alliances for technician workforce development;
- faculty development and enhancement;
- human resource issues including recruitment, retention, and placement of students;
- curriculum and program development and improvement; and
- secondary school education for candidates for advanced technician careers.

This workshop report presents issues and recommendations relevant to the education of science and engineering technicians. The audience for this report includes: (1) administrators and faculty of academic institutions at all levels, but particularly in two-year colleges; (2) employers of technicians (companies, government agencies, universities, and others); (3) leaders of professional societies in science, engineering, and technology; and (4) federal, state, and local government officials who have responsibilities for the quality and quantity of the nation's technical workforce. The recommendations in the report are clustered under the charges of the working groups. Because there were many cross-cutting themes, a few highlights of the recommendations that address all concerned groups are given in this summary.

Administrators and faculty, employers, professional societies, and government working together must:

- recognize that new educational strategies will require their commitment and cooperation as well as input from technical personnel in all groups.
- formally recognize the accomplishments and unique professional characteristics of science and engineering technicians.
- support and disseminate information that identifies, develops, monitors, and highlights careers of technicians.
- catalyze educational reform that gives a high priority to faculty enhancement and preparation.
- address essential standards for the development of technical curricula and assure quality programs through accreditation of programs and other similar means.

- enhance academic mobility through articulated curricula with emphasis on applied content knowledge and skills.
- develop systems that value racial, gender, and cultural diversity and promote the prestige and importance of technicians.
- establish job classifications based on voluntary industry standards to provide career ladder opportunities for technicians.
- provide recognition and award programs for students and those involved in technician education.
- establish successful alliances to support educational and professional activities for technicians.

  These alliances must:

  - work cooperatively in planning, prioritizing, and funding educational programs that produce high quality technicians.
  - support programs that prepare future faculty and teachers in technical programs.
  - provide regular opportunities for faculty and teachers to update content knowledge and pedagogical skills and remain current with technological developments.
  - support working technicians with opportunities for educational and professional development and enhancement.
  - encourage sharing of resources among all partners.
  - collect and disseminate data on science and engineering technician careers and opportunities and provide this information to students, parents, and the general public.
  - support the development and delivery of comprehensive and flexible instructional materials and programs for technician education.

In general, technician education programs should:

- make experiential, contextual, and collaborative learning an integral part of education.
- assure an adequate foundation in mathematics, science, and technology.
- develop student competencies in written communication, oral communication, and data acquisition and interpretation.
- incorporate advanced instructional technologies including computer networks, multimedia, and applications software.
- recruit faculty and teachers with appropriate educational and work place credentials.
- provide faculty and teachers with appropriate time and resources for course and material development.
- supply appropriate facilities and equipment for effective teaching of technical courses.
- provide opportunities for internships in industry for students, faculty, and teachers.

THE FUTURE

Mounting a major national effort to improve the education of technicians at this time will benefit greatly from the recognition by many employers that technicians are critical to future competitiveness and to achievement of work place management reform efforts. Furthermore, the interest of academic institutions in reform should enable technician education to gain its rightful place in American education.

Implementation of recommendations in this report requires all groups involved in technician education and employment to take a much more proactive effort than in the past. Technician education has become a priority for the National Science Foundation as well as other government agencies. The current Administration and Congress have demonstrated their commitment to technician education by support of new legislation as well as many policy statements. Ensuring the cooperation by all stakeholders in technical education will enable the nation to provide a highly qualified workforce for tomorrow. Two-year colleges must plan and work cooperatively with employers in business, industry, and government; four-year colleges and universities; secondary schools; and professional societies to improve the quality of the United States technical workforce. No one group can do it alone. All must cooperate. With continued support from the National Science Foundation and others who share the vision, our nation can maintain a competitive edge and meet the challenges for the future while providing a safe and clean environment for its population.

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INTRODUCTION

On July 21-23, 1993, the American Chemical Society, the American Society for Engineering Education, the FCCSET CEHR-CIT Joint Working Group on Technical Education, the FCCSET Working Group on Undergraduate Education and the National Science Foundation co-sponsored a workshop, *Gaining the Competitive Edge: Critical Issues in Science and Engineering Technician Education*, to address issues relevant to ensuring the high quality of science and engineering technicians in the United States. This workshop was timely and extremely important because it has become increasingly apparent that for the United States to remain competitive in the world market, the technical component of the workforce in the United States must be as well prepared as the corresponding technical workforce in other industrialized countries.

The purpose of the workshop was to identify critical issues in science and engineering technician education; to develop recommendations for industry, academe, and government; and to engage these communities to actions. Deliberations focused on strategies to strengthen two-year college technician programs. However, improving education programs for prospective technicians at secondary school and expanding opportunities for technicians at four-year colleges and after employment were addressed as well.

The 115 participants who attended the workshop represented high technology companies, two-year colleges, four-year colleges and universities, secondary schools, professional societies, and federal agencies with interest in the education of technicians. The participants were divided into six working groups to examine the following issues:

- professionalism of technician careers;
- alliances for technician workforce development;
- faculty development and enhancement;
- human resources issues including recruitment, retention, and placement of students;
- curriculum and program development and improvement; and
- secondary school education of candidates for advanced technician careers.

This workshop report presents issues and recommendations relevant to the education of technicians. The audience for this report includes:
(1) federal, state, and local government officials who have responsibilities for the quality and quantity of the nation's technical workforce;
(2) administrators and faculty of academic institutions at all levels, but particularly in the two-year colleges; (3) employers of technician personnel (companies, government agencies, universities, and others); and (4) leaders of professional societies in science, engineering, and technology.

BACKGROUND

Since the publication of *A Nation at Risk* in 1983, the educational system of the United States has been subjected to intense scrutiny and study. Changes in the understanding of how students learn have lead to reforms of K-12 education which emphasize that all students need to construct their own knowledge. This reform movement has lead to the development of mathematics and science standards which can be used to determine when quality mathematics and science teaching is occurring in classrooms. At the college level, the changes needed for science and engineering education were not clearly evident because several measures suggested that the United States could arguably claim to have the best science and engineering colleges and universities in the world. Neither did the nation appear to have a great shortage of engineers and scientists. However, in mathematics, chemistry, and physics, the structure of the introductory courses was being challenged leading to reforms in these courses. As enrollment in engineering courses dropped, there was renewed emphasis on engineering education, particularly the role of design.

The decade also witnessed a reduction of the U.S. technological and manufacturing lead to other industrialized countries. To regain the competitive edge, many leaders in industry, education, and government recognize the need to change the education of those in the work place. In 1990, the report, *America's Choice: High Skills or Low Wages*, by the Commission on the Skills of the American Workforce of the National Center on Education and the Economy found that

> *"America may have the worst school-to-work transition system of any advanced industrial country." and "Our approaches [to education and training] have served us well in the past. They will not serve us well in the future."*

The Commission also noted that companies adopting new work management systems that engaged more employees in decision-making and that required better educated employees were achieving renewed competitiveness through spectacular advances in productivity, quality, and variety. Although highly competent scientists and engineers were being produced in sufficient quantity by the nation's schools and colleges, far too few science and engineering technicians of comparable quality were being produced.

Increasing attention and a multitude of reports began to focus on the portion of the population (about 70% according to the National Center on Education and the Economy) whose ability to produce high quality work does not require a baccalaureate degree. Many science and engineering technicians are included in this workforce, although some continue formal education to a bachelor of technology level.

Two-year colleges and some four-year colleges and universities provide the Associate of Applied Science (A.A.S.) degrees that produce entry-level qualifications for many technicians. In addition, a number of colleges offer Bachelor of Technology programs. These programs have not achieved high visibility and broad support in the past, although a few have benefited from support by the college-level programs of the National Science Foundation (NSF).

Both Congress and the White House emphasized the technical workforce in their 1992 and 1993 initiatives. Congress passed and the Administration supported the *Scientific and Advanced Technology Act of 1992*, which called for the National Science Foundation to establish a national program to improve the education for technicians in advanced technology fields utilizing the resources of the nation's two-year colleges.

Mounting a major national effort to improve the education of science and engineering technicians at this time will benefit greatly from a definition of the role of technicians by employers. Technicians are not junior scientists or engineers nor are they trained to do routine tasks. They are professionals in their own right with unique skills and understandings which are critical to future competitiveness. They work on applications which are built on theoretical understandings. The current national interest in educational reform should position technician education to provide the understanding of concepts and processes needed to develop highly qualified technicians.

THE WORKSHOP

The format of the workshop was designed to give participants opportunities to consider broad issues as well as strategies in the particular area to which they were assigned. With the assistance of the planning committee and NSF staff, participants received assignments prior to the workshop designed to stimulate their thinking on six critical issues. Two-year colleges, secondary schools, four-year colleges and universities, employers, and professional societies concerned with this field were targeted in this effort. This workshop was an effort to charter new directions in technician education, career path development, and professional recognition.

The issues associated with science and engineering technician education were divided into six areas. Each interdisciplinary working group addressed one of these six topics at the workshop:

■ **WORKING GROUP A:**

Professionalism of technician careers

To consider how to enhance the role and image of science and engineering technicians as professionals with unique expertise.

■ **WORKING GROUP B:**

Alliances for technician workforce development

To explore how academic institutions, employers (industry, business, universities, and government), and professional societies can effectively work together to educate high quality science and engineering technicians.

■ **WORKING GROUP C:**

Faculty development and enhancement

To ensure that technician educators at all levels possess both the subject matter competence and effective pedagogical skills required to help students attain the highest level of technical competence.

■ **WORKING GROUP D:**

Human resources issues including recruitment, retention, and placement of students

To explore ways to recruit and retain students on a technical career path and to place graduates in positions that utilize their unique skills.

■ **WORKING GROUP E:**

Curriculum and program development and improvement

To ensure that curricula in associate degree programs for technicians are relevant, effective, and appropriate for applied careers.

■ **WORKING GROUP F:**

Secondary school education of candidates for advanced technician careers

To develop secondary school curricula and programs that provide students a foundation for future educational work, meaningful work experiences, and applicable career information.

As the working groups tackled their assigned issues, recommendations evolved that fit better for reporting purposes in the issue areas assigned to others. Thus, the following recommendations are arranged by issues rather than by working groups.

Full implementation of the recommendations presented in this report could greatly improve the American workforce because: (1) young people would be able to make a technician career a first choice instead of (a) using it as a defensive safety net when early career dreams are shattered, or (b) discovering this opportunity only after gaining expensive, time-consuming experience as an adult; and (2) all new-hire technicians would arrive for their first full day of work with a sound foundation of knowledge and skills developed with strong employer input and guidance.

CLOSING

The atmosphere throughout the workshop was very upbeat and positive. The consensus among the participants was that this was an extremely important time to address issues in the education of science and engineering technicians. Two-year colleges must plan and work cooperatively with employers in business, industry, and government; four-year colleges and universities; secondary schools, and professional societies on ways to improve the quality of the United States technician workforce. No one group can do it alone; all must cooperate. Working together academia and employers can improve the quality and effectiveness of technician education. With continued support from the National Science Foundation and others that share this vision, our nation can remain a leader in the world economy and meet the challenges for the future.

WORKSHOP REPORTS

PROFESSIONALISM OF TECHNICIAN CAREERS

Understanding the role of technicians in the modern technical work place is a key element to providing appropriate educational experiences for both prospective and employed technicians. Technicians employ techniques using complex technologies that transform materials into useful products and maintain and modify physical entities, and services provided by technicians often are not highly visible to others. While they often work side-by-side with other professionals, they are not junior scientists and engineers nor are they trained to perform routine tasks. Their work emphasizes skilled technical applications, requiring a good theoretical grounding. Stephen R. Barley (Barley and Bechky 1993) states that his research shows that technicians "employ technologies and techniques to transform aspects of the material world into symbolic representations." Barley's research shows that the technician's role is misrepresented when it is described only as a subset of a professional's role by terminology such as "semiprofessional" and "junior professional." In recent years, many technicians and some of their associates have asserted that science and engineering technicians should be considered as professionals with a unique expertise that differs significantly from that of scientists and engineers.

Academic institutions, employers, scientific and engineering professional societies, and accrediting bodies are all participants in the improvement of technician education and careers. Thus, they should address the professional status of technicians in the United States.

ISSUES

The issues addressed included:

- requirements for technician pre-employment and continuing education;
- accreditation, voluntary industry standards, and other means of providing assured quality of associate and baccalaureate degrees in technician and technologist education;
- certification of technicians;
- relationships between two-year associate degree programs for technicians and four-year programs for scientists, technologists, and engineers; and
- contributions of technicians to science and engineering.

RECOMMENDATIONS

Employers Should Recognize and Emphasize the Professional Characteristics of Technicians

Individual employers, whether private or public, provide recognition to their technicians and create conditions that maximize technician performance. Such recognition encourages students to consider technician careers. Thus, these employers should:

- formally recognize the accomplishments and acknowledge the professional characteristics of science and engineering technicians through public statements and by establishing and providing attractive career ladder opportunities.
- eliminate cultural barriers to science and engineering technician jobs, and create an environment that acknowledges the important role that technicians serve in the high technology work place.
- design job classifications to recognize associate degree science and engineering technicians and baccalaureate degree technologists in business and industry as well as in civil service.
- join with academic institutions to support and disseminate research information that identifies, develops, and monitors success for the science and engineering technician pipeline from the educational institution to the work place and in the work place itself.
- ensure that young people are aware of opportunities for technicians in the work place and the educational requirements to succeed in the profession.
- provide working technicians with information about pertinent educational and professional opportunities including college courses, workshops, seminars, membership in professional societies, professional meetings, and other means by which to keep up-to-date in the profession.

Professional Societies Should Recognize and Emphasize the Professional Characteristics of Technicians

Professional societies that currently serve scientists and engineers can provide recognition for technician contributions to these disciplines, provide opportunities for technicians to work with others in society activities, and develop communication links among technicians, scientists, and engineers. Societies should:

- support the professional development of technicians through their existing structures or through related societies for technicians.
- assume a leadership role in bringing together federal and state agencies, industry and union leaders, working technicians, and public entities to address essential standards for technical curricula and continued updating of job skills.
- strengthen or initiate activities that support the continual learning and networking of technicians associated with their respective disciplines. Such activities may include technician recognition programs, membership divisions for technicians, workshops, seminars, regional meetings, publications, and image enhancement activities.
- provide awards and leadership opportunities for technicians and technician educators.

Government Agencies Should Support Activities that Ensure Quality Technician Education Programs

To foster creation of a well-educated and professionally recognized technician cadre, government agencies should:

- support activities focused on the development of essential educational standards for science and engineering technicians that ensure an adequate base of science and mathematics to satisfy immediate job requirements and future education needs. Standards for technician education should build upon the recommendations developed by the mathematics and science education standards projects. Also, recommendations from the industry standards projects should be incorporated into technician education standards.

- support activities of technician accreditation efforts to ensure quality programs.

Academic Institutions Should Use Accreditation and Other Procedures to Foster High Quality Technician Education Programs

Academic institutions that educate technicians and accrediting agencies can contribute directly to developing professional characteristics of highly qualified technicians. Thus, two- and four-year colleges and universities should:

- enhance upward academic mobility (e.g., from Associate of Applied Science to Bachelor of Engineering Technology programs) through articulated curricula with emphasis on applied content knowledge and skills. Bridging or transitional programs should be available where necessary.

- seek to achieve program accreditation for science and engineering technician programs by recognized accrediting bodies.

- encourage faculty and students to participate in professional society activities.

Technicians' Responsibility for Their Own Professionalism

As professionals, science and engineering technicians/technologists should:

- take advantage of leadership, learning, networking, and certification opportunities offered by professional/technical societies and other organizations to enhance their recognition as members of science and engineering teams.

Effective technician education demands a close relationship between employers and academic institutions. All working groups recognized this as an important component in technician education. Working relationships between academic institutions and employers have long been a part of technician education in many locales, and almost every technician curriculum has an employer advisory committee. Cooperative education has a rich history at many institutions, and employer-sponsored scholarships are broadly available.

What is new about the following recommendations about employer/academic institution alliances is the sense of urgency for increasing the depth and breadth of involvement in technician education by many more employers. Companies have a vested interest in technician education in two-year colleges because they are recipients of many services offered by two-year colleges as well as the employers of technicians educated in associate degree programs. Too many prospective technicians have never had a working contact in their field of study. Much of the experience with materials and equipment needed by new technicians cannot be provided by educational institutions. And as suggested by the SCANS report (U.S. Department of Labor 1991), some competencies expected in today's work place cannot be provided by educational institutions alone. Addressing such problems is one of the objectives of employer/academic alliances.

ISSUES

Educational institutions and employers of technicians must work cooperatively to improve the quality of the United States' technician workforce. The issues on creation of alliances and sustained cooperation among partners included:

- recognition that support for pre-career technicians must be provided for secondary school programs; and for certificate, associate, and baccalaureate degree programs in two- and four-year colleges;
- articulation between educational institutions at different levels;
- participation by employers in the educational process (e.g., providing content expertise and adjunct faculty, making special facilities available to students and faculty, and supporting faculty and work experiences at employer work sites);
- recognition and award programs for institutions, educators, and students; and
- foreign models of alliance relationships that support technician education, and implementing components of those models as appropriate.

RECOMMENDATIONS

Alliances may be organized to support educational and professional activities as a cooperative activity involving companies, professional societies, educational institutions, and government (federal, state, and local) agencies. An alliance may operate at national, regional, state, or local levels, with each level providing unique strengths for improving education and professional opportunities for technicians.

Technician education is often considered the province of associate degree-granting institutions. However, these institutions are part of a continuum of education in this country, and alliances for technician education must be considered by other sectors of the education community as well.

Thus, a successful alliance must:

- include technician educators and technicians in alliance leadership roles.
- define its own missions and goals.
- consider all partners as equals and ensure that all partners benefit from the outcomes.
- identify benefits for each member of the alliance.
- integrate services that lead to a sharing of resources.
- leverage strengths through facilitating the use and brokering of local assets.
- improve the quality and strive to reduce the cost of technician education.
- adopt standards of performance and encourage implementation of programs that enable technicians to meet such standards.
- develop programs that provide effective contextual learning situations.
- support programs specifically designed to enhance technical education as well as promote science, mathematics, and technology education in secondary schools.
- promote professional programs (e.g., seminars, workshops, and internships) that supplement technician education.
- assist four-year degree programs in technology as well as contribute to education in traditional science and engineering fields.
- consider foreign models of technician education that may be adapted to American conditions.
- develop systems that value racial, gender, and cultural diversity and promote the importance and prestige of technicians.

Academic Institutions Should Use Accreditation and Other Procedures to Foster High Quality Technician Education Programs

Established Alliances Must Sustain Continual Improvement

To ensure that alliances sustain continual improvement beyond the lifetime of start-up or "seed" investments, a successful alliance must also:

- demonstrate at each operational level a strong, ongoing commitment to cooperation by all partners in the alliance.
- promote educational reform that gives a high priority to faculty enhancement, ensures effective articulation and smooth transition among technical programs, and provides many opportunities for students at all grade levels to acquire knowledge and skills in a learning process that uses appropriate contextual settings and hands-on experiences.
- support the needs of academic institutions for appropriate facilities, instructional equipment, qualified and highly skilled instructors, and other factors that are essential in technician education.
- help create a globally competitive and high quality technological workforce by developing seamless technical education that promotes sound academic underpinnings, up-to-date technical content, articulation of courses across institutions, and technicians' continued professional development.
- engage in outreach activities to the local community, such as providing technical services to businesses and industry.
- provide recognition and award programs at local, regional, and national levels for students, instructors, and/or institutions involved in technician education.

Government Agencies Should Support Alliances

Government agencies at both federal and state levels should:

- work cooperatively in planning, prioritizing, and funding to facilitate development and improvement of local, state, regional, and national alliances that ultimately enable the delivery of educational programs that produce high quality technicians. This work should include establishing one or more clearinghouses (perhaps through professional societies) that would leverage resources among alliances, characterize effective alliances, provide evaluation strategies, and disseminate information.

FACULTY

The most crucial element in classroom and laboratory education for technician students is the quality of the faculty. It is the faculty who implement the curriculum and utilize instructional materials while using their expertise for effective education of the students they teach. To develop well-educated technicians, each faculty member must be current in content, effective in pedagogy, and knowledgeable about assessment. The preparation and continuing education of science and technology educators in secondary schools and colleges and administrators are thus critical.

ISSUES

Academic, business, industrial, and other experiences are needed by educators who teach pre-career and employed technicians and administer such programs both at secondary school and at college levels. The issues addressed for this area included:

- appropriate levels of formal education for technician educators;
- work experiences that a technician educator should bring to the classroom or laboratory;
- continuing education for technician educators;
- educator participation in professional activities such as work experiences at employer locations, research, and consulting;
- educator participation in professional activities and scholarly work in their disciplines such as publication of articles, textbooks, software, and laboratory manuals; presentations at professional meetings; and service to societies;
- local, regional, and national recognition programs; and
- roles for nonacademic professionals in instructional activities for technician education.

RECOMMENDATIONS

Most educational institutions involved in technician education are aware of the need for updating the content knowledge and improving the teaching capabilities of their faculty. Also, many of these institutions are cognizant of the critical role of contextual learning, including projects, which enable students to become highly skilled technicians. Thus, technician educators must be provided opportunities for close, continual contact with technician work places. In addition, educators must engage in regular academic activities to update content knowledge and maintain currency in technological developments.

Educational Institutions and the Technical Competencies of Their Faculty

As a response to such needs, educational institutions should:

- recruit faculty for two-year associate degree programs with appropriate industrial experience in addition to baccalaureate or higher degrees in mathematics, technology, science, or engineering. For technician instruction in two- and four-year colleges, professional registration should be encouraged.

- require faculty teaching in technical programs to have qualifications as recommended by professional societies and organizations that implement accreditation standards.

- require that faculty members in four-year colleges and universities involved in the specific preparation of future teachers for technician education programs have industrial experience.

- encourage and support faculty members who teach technical specialty courses in both two- and four-year institutions to update their technical knowledge of advances made in their field through work in industry at regular intervals.

- enable college faculty and secondary school teachers who teach mathematics, science, and other courses for technicians to obtain effective exposure to the technical work place by:
  - having an institutional commitment to support work experiences for faculty and granting leaves for short industrial internships.
  - encouraging that some courses be delivered on-site to meet employer's needs and to develop in instructors a sense of the work place environment.
  - providing educators with opportunities to participate with groups of employees in industrial training and orientation programs.
  - making industrial technical training aids and materials available to teachers.
  - encouraging faculty to take part in national training programs.

As described by the SCANS report (U.S. Department of Labor 1991), more is expected of today's academic institutions than a mere passing on of concepts and isolated skills. Thus, both new and experienced teachers must consider their teaching competencies as seriously as their content knowledge competencies.

Educational Institutions and the Teaching Competencies of Their Faculty

Academic institutions should:

- create flexible, on-campus programs of mentoring or coaching by master teachers; and present on-campus discipline-related professional development activities.

- adopt faculty teaching load limits that provide adequate time for preparing instructional materials for laboratory activities and classroom presentations.

- provide appropriate time and facilities and equipment for effective teaching of technical courses.

- encourage colleges and universities and other relevant organizations to develop efficient innovative educational programs to transform scientists, engineers, and mathematicians with recent industrial or military experiences into effective teachers for technical programs.

- include a variety of pedagogical skills in the creation of instructor educational programs at both preservice and inservice levels and in the evaluation of teaching, such as ability to:
  - design instructional strategies and materials that foster analytical thinking and problem-solving skills.
  - engage and motivate students.
  - evaluate the effectiveness of instructional strategies and needs of students.
  - implement models of effective, proven teaching methods.
  - stimulate student teamwork through cooperative learning.
  - support innovative teaching strategies for a diverse group of students.
  - teach and exhibit the principles of contextual learning.
  - use hands-on equipment and procedures appropriate to the instructional area at a high skill level.

- encourage sharing resources among educators at all levels from secondary school through the work place. Examples include participation in professional society activities, use of computer networks and innovative instructional technologies, joint offering of courses and team teaching, and sharing equipment.

Effective Technician Education Requires Sharing Resources from Secondary Schools to Colleges to the Work Place

- overcome traditional barriers that separate classrooms and work places in space, in time, and in fundamental modes of thinking and learning. Examples of strategies to be employed are:
  - forming instructional teams of specialists across traditional departmental lines.
  - scheduling and locating classes with more flexibility.
  - teaching basic science and mathematics through the vehicles of real-world technical problems and industrial scenarios.
  - encouraging the collaboration of industrial and academic scientists and technicians.
  - using industry-standard equipment for laboratories so that learning takes place in a realistic setting.
  - using employer laboratories, libraries, and databases to provide appropriate educational experiences.

Government Agencies Should Support Teacher Preservice and Inservice Programs

The National Science Foundation and other government agencies should:

- support programs that prepare future technician educators including both secondary school teachers and college faculty.

- support enhancement activities, including workshops, seminars, and internships in industry, for technician educators who are currently teaching in secondary schools and colleges.

HUMAN RESOURCES ISSUES – RECRUITMENT, RETENTION, AND PLACEMENT

Ultimately, the purpose of this workshop was to explore and recommend programs to meet the needs of both the students choosing to make careers as technicians and the employers who hire them. Workshop participants recognized that students in technician education today are a heterogeneous population, with academic credentials that vary from some high school education to associate degrees to baccalaureate science and engineering degrees. Some students come directly from secondary school; others are already technicians or have other four-year degrees and seek to improve their qualifications through continuing their education. Increasingly, more adults are returning to college after being a part of the workforce where they have limited opportunities for better economic mobility. Many potential students are not aware of science and engineering technician opportunities. Therefore, these diverse students should be identified, counseled, recruited, retained and guided into careers with viable professional options. Academic institutions, business, and industry should work closely together to assure that jobs and career opportunities exist for students who complete these technical programs and help place them in suitable positions.

ISSUES

Educational institutions, employers, and professional societies all have responsibilities for providing assistance that enables aspiring technicians to attain their career goals. The issues addressed for this area included:

- initial and continuing education requirements for technicians;
- recruitment and retention of students and placement of graduates with particular attention to women and to others who are underrepresented in technical fields;
- assessment and exploration of interests and aptitude;
- workforce supply and demand for technicians;
- linkages between on-the-job-training (OJT) provided by employers and education and training provided by educational institutions;
- recognition that students in technical programs may have diverse backgrounds which vary from those with some secondary school work to experienced employees seeking upward mobility to those re-entering the workforce;
- needs of students who already hold degrees in other fields who are utilizing technician programs for upward economic mobility;
- needs of those who will enter the job market immediately upon completion of an associate degree, and the needs of those who wish to continue in four-year programs in science, engineering, or technology;

- student support services required to improve retention and success potential (e.g., tutoring, mentoring, baby-sitting, job placement, advising, etc.); and
- agreements with employers for cooperative education, internships, and other arrangements that offer students job-related experience.

RECOMMENDATIONS

Employers and Alliances Have Important Roles in Helping Students Become High Quality Technicians

Employers who demand top quality technicians must ensure that local institutions involved in educating technicians have appropriate resources, and they should encourage their own employees to use these resources. Better relationships must be developed, resources leveraged, and new creative approaches tried. Thus, employers and alliances should:

- seek ways to provide or share state-of-the-art equipment. They should help ensure that faculty members have adequate content knowledge and understanding of the work place so they can teach prospective technicians effectively at both secondary school and college levels.
- build relationships to foster long-term commitments to provide faculty internship opportunities or other faculty enhancement activities in the work place.
- support continuation of necessary and effective technician programs, through financial and other means, that may have enrollments too small to permit continuation according to standard school requirements.
- encourage legislative leaders and state government policy makers to recognize the community benefits provided by differentiated funding for investment in technical programs.
- recognize that new educational strategies may require their commitment, cooperation, and input from technical personnel in the work place in the design and/or implementation of innovative curricula. Employers should be cognizant of a growing trend for teaching roles to become an in-kind support function of some technical personnel.
- recognize that the diversity of the U.S. population requires the development of incentives for minorities and females to enter technician education as students, teachers, counselors, and administrators.

Colleges Should Have a Commitment to Student Diversity

Technician careers often can be attained with a relatively short time investment in education. As a result, such careers attract students with highly diverse backgrounds in academic achievement and work experience. To address such diversity, colleges should build or strengthen partnerships with employers to develop strategies for:

- recruitment and retention of students and placement of graduates with particular attention to women, minorities, people with disabilities, and students who have been in the workforce (including work at home) as well as recent secondary school graduates.

Knowledge about the characteristics of technical work places is critically absent, if not misunderstood, by the general population. Even so, students, or their parents, often are asked to make life-impacting selections of courses and curricula as early as junior high school. Both secondary schools and colleges should:

Secondary Schools and Colleges Should Provide Technician Career Information

- increase efforts to provide career exploration opportunities, information, access to role models, guidance, and counseling about technician careers to students, parents, and the general public. Such activities should be integrated into daily instruction beginning in the elementary schools. The voluntary industry standards projects should provide useful information about technical careers.

- help students understand that their attitude and performance in school are directly related to job and career opportunities.

Alliances Should Address Student Needs

Industrial employers, government agencies, professional societies, and academic institutions should:

- build or strengthen alliances to create innovative methods for the recruitment, placement, and retention of science and engineering technicians and students.

- develop strategies to reduce and eliminate cultural barriers to technician job satisfaction, and to create an environment that acknowledges the value of their role.

Government Agencies and Professional Societies Should Be Responsive to Student Needs at All Levels

The National Science Foundation, other government agencies, and science and engineering societies should:

- collect and disseminate data about science and engineering technician careers and opportunities as well as about the educational needs for such technicians. This information can be used to support public policy on workforce supply and demand and guide academic institutions in program development.

- support the development and delivery of comprehensive and flexible instructional materials and programs that respond to the diverse needs of students, employees, and employers. The needs include: (1) fast response to new developments in technology; (2) creation of instructional materials that can be implemented with great flexibility; and (3) delivery of instruction and information by satellite and computer networks, and other nontraditional methods.

- support and disseminate results of research that identifies, develops, and monitors measures of success through the science and engineering technician pipeline from pre- to post-employment.

As the rate of technological advancement and work places demand for integration of traditionally separate disciplines increases steadily, there are continual pressures to teach pre-career and employed technicians more content in a shorter time. Thus, curriculum designers are faced simultaneously by a heterogeneous student body and by increasingly complex content requirements with stricter time constraints. Curricula for technicians must be continually reviewed and updated to meet these diverse needs.

Tech Prep concentrates on contextual learning situations and applied academics, including applied mathematics, applied sciences, and applied communications.

Apprenticeship programs may consist of formal, prescribed education to which work experience is added.

Cooperative education consists of alternating work periods and school periods.

Career academies operate as a subunit in a secondary school environment.

While facing the reality of older students currently in technician education programs, policy makers seek ways to make transition from school to work more effective. If the educational reform efforts of Tech Prep, apprenticeships, cooperative education, and career academies achieve their goals, the average age of students in technician programs will start falling during this decade. Further, articulation between secondary school programs and post-secondary technician programs is being advocated and supported by government, business and industry, and education leaders. Various initiatives such as the NSF Advanced Technological Education program and Tech Prep have already started such activities.

New challenges face curriculum developers in technician education programs as they merge work place demands, society needs, and implement recommendations from a variety of national standards projects. Mathematics education standards (NCTM 1989) have been well developed by the National Council of Teachers of Mathematics (NCTM) and implementation efforts led by NCTM and various NSF-supported projects are underway. Special attention should be directed to the American Mathematical Association of Two-Year Colleges (AMATYC) standards (AMATYC 1993) expected to be released in 1994. Science education standards are being developed by the National Research Council and should be in place by late 1994.

The criteria for accreditation of engineering technology programs by the Technology Accreditation Board (TAC) of the Accreditation Board of Engineering and Technology (ABET) should be considered for engineering technician and technologist education. The American Chemical Society (ACS) approval program for chemical technician education should be similarly considered. Voluntary industry standards intended to reflect industry expectations of knowledge and skills of new employees are under development and draft standards for some science and engineering technician areas should be available by late 1994.

As new programs develop and older programs are reformed to address changing needs, there must be continuous reformulation of curricula and instructional materials. Discussion focused on the development of model instructional programs in advanced technology education.

ISSUES

The issues addressed included:

- design of comprehensive technician education programs based on a strong foundation of basic mathematics, science, and engineering principles;
- application of the content and philosophy of mathematics and science education standards to technician education;
- identification of the necessary contributors to curriculum design and instructional materials development;
- establishment of innovative alliances and partnerships including national consortia for curriculum design and instruction as well as materials development;
- coordination of curricular change across institutional boundaries;
- joint development and dissemination of instructional materials among secondary schools, two-year colleges, and four-year colleges and universities;
- role of instructional media in innovative technician education programs;
- evaluation of programs, courses, instructional materials, and instruction processes and assessment of student learning;
- acquisition, maintenance, and upgrading of equipment; and
- development of courses and programs that facilitate transfer to other programs or institutions (other technician programs, science and engineering programs, four-year technology programs, etc.).

RECOMMENDATIONS

Two-year Colleges Must Be Flexible and Still Provide for Lifelong Learning Foundations

Recognizing that they have been the traditional focus of technician education, two-year colleges; individually and through local, state, and national consortia; should:

- ensure that associate degree technician programs play a central role in the continuum of education from secondary school programs through the baccalaureate degree.
- accommodate the diversity and learning styles of adult learners and ethnic minorities.
- provide multiple entry and exit points.
- deliver instruction in both campus and work site settings.
- fit the time constraints of both traditional and nontraditional student schedules.

- provide curricula for science and engineering technician education that lay foundations for lifelong learning, while satisfying the more immediate needs of the rapidly changing technical work place. Such curricula should include three essential components:
  - General component — mathematics and science, written and oral communications, and computer skills appropriate to the work goals and learning styles of technicians, and as pre- or co-requisites to technical and industry-specific components.
  - Technical component — discipline-specific knowledge and skills that are fundamental to the field.
  - Industry-specific component — knowledge that is required for local needs and for technological changes.
- make experiential, contextual, and collaborative learning an integral part of the programs by utilizing a variety of techniques such as relevant laboratory-based activities, simulations, internships, and cooperative education.

Mathematics is a Key Foundation for Technician Education

The application of mathematics to technical problems is fundamental to all technician education programs. A statement of the mathematics prerequisite is the most common way to describe the "rigor" of a technical program and individual technical courses. All participants felt that a strong foundation in mathematics was an absolute requirement for technician education; however, there was a divergence of opinion about what form the mathematics coursework should take.

Some members of the group believed that two-year colleges should:

- ensure an adequate foundation in mathematics for technician education by requiring a prerequisite of two years of secondary school algebra and one year of geometry or its equivalent as minimal entry qualifications. To provide adequate skills and knowledge for technicians to enter the advanced technological workforce, the minimal mathematics requirement in two-year programs should be college algebra and trigonometry courses with calculus and/or statistics being strongly recommended for appropriate programs. These courses should integrate technical applications throughout.

Others believed:

- that traditional mathematics courses at both secondary school and college levels should be replaced by courses of a different design and be implemented through different pedagogical strategies. For example, statistics may be more valuable than some traditional advanced algebra topics; science and mathematics courses may be integrated; or a stronger emphasis on applications may be appropriate.

Additional Workshops Should Determine Appropriate Content of Core Courses in Science and Mathematics for Technician Education

A parallel concern applied to the laboratory-based science courses, particularly physics and chemistry, that are used to support technician education. Thus, the group recommended that:

- workshops be held to determine appropriate content of application-driven core courses in science and mathematics, both at the secondary schools and two-year college levels. The content of the courses should reflect the National Research Council (NRC) and the NCTM Standards at the secondary level. At the two-year college level, the content and pedagogy should reflect the AMATYC Standards. Specific mathematics and science courses that are recommended should reflect the different needs among technician programs.

Alliances Have a Role in Curriculum Development and Dissemination

Alliances and partnerships, including professional societies, industry consortia, and educational institutions are the major stakeholders in technician education. By ensuring representation from all groups and serving as communication channels, such alliances and government agencies should support the development of:

- curriculum frameworks or guidelines for program implementation. These efforts will serve to stimulate program implementation and supportive activities such as instructional materials development. Successful implementations, which can serve as model programs, should then be disseminated through NSF-supported Centers of Excellence, professional meetings, publications and reports, consultants, and other means.
- programs for contextual learning through authentic hands-on experiences with equipment, apparatus, and procedures that are relevant to the work place.
- model curricula and programs. They also should provide support to disseminate such curricula; acquire up-to-date and appropriate equipment; and improve articulation of courses and programs among educational institutions.

Academic Institutions Should Make Extensive Use of Educational Technology in Technician Education

Opportunities to improve technician education through educational technology are numerous and underutilized. Thus, secondary schools and colleges should:

- seek to maximize student mastery of content and to ensure that graduates are prepared to continue their professional growth by using model curricula that incorporate comprehensive instructional support systems. These must utilize advanced technologies including computer networks, multimedia, applications software, courseware, and data acquisition technologies. Delivery strategies should serve to increase access to curricula both on campus and at the worksite.
- improve access and support for faculty professional development.

SECONDARY SCHOOL EDUCATION FOR TECHNICAL CAREERS

For the last few decades, success of secondary schools has been determined primarily by statistics describing admission to four-year college programs. However, many students have not responded well to academic track programs, with the result that many potential technicians spend four years in secondary school programs that prepare them neither for jobs nor continued education. Many of these students find their ways into technician education programs only after spending many years in low-paying, dead-end jobs; others develop sufficient skills to become classified as technicians lacking the opportunity for upward mobility. This portion of American youth is being targeted by some of the new initiatives of the current administration. Among the best known school-to-work transition programs are Tech Prep, apprenticeships, cooperative education, and career academies.

ISSUES

Studies have indicated that the education of those entering the workforce as technicians and plant workers has been particularly deficient at the secondary school level. Tech Prep is one national reform effort that addresses this issue. It currently has many forms of implementation and still is in an early state of development. Other models of educational reform also have shown impressive results in raising student qualifications, while simultaneously improving retention. The issues addressed included:

- design of curricula and instructional materials that provide foundations for technician education and linkages to college and employer training programs;
- coordination between technical specialty areas, such as electronics, and other course areas, including communications, mathematics, computer applications, and physics;
- assessment of student learning for the benefit of curriculum and program improvement;
- needs of students who may pursue other career choices, including science and engineering, after completing part of a secondary school Tech Prep program;
- nontechnical employment opportunities that may be served well by education designed for technician careers;
- alternatives to the Tech Prep secondary school route for technician education;
- enhancement and preparation for preservice and inservice teachers in technician education programs, including those teaching core and specialty courses; and
- guidance and career information on technician careers for middle and secondary school students.

RECOMMENDATIONS

Recognizing that technology must be used by all U.S. citizens and that the ability of the nation to compete internationally demands technically competent technicians and production personnel, workshop participants recommended that secondary schools enable:

Secondary Schools Should Provide All Students Direct Experience with Technology

- their teachers to work with faculty from two- and four-year colleges to implement existing model programs or to develop more effective school programs.
- practical applications to be integrated continually into academic courses.
- every student to build, and/or repair, invent, and innovate as well as to use computers and other design tools.
- every student to master a core set of competencies benchmarked to international standards, yet consistent with American needs, at Grade 9 or 10 in mathematics, science, communications, social studies, technological literacy, critical thinking, and problem-solving. Students who lag behind their colleagues at any time should be provided extra assistance. Those who lack the required mastery by Grade 10 must receive the extra assistance and time necessary to master the core.
- facilities to remain open after regular school hours for enrichment activities that allow students access to computers, hands-on technologies, libraries, museums, etc.

Educational Institutions Should Ensure that Teachers of Pre-technicians Are Intimately Familiar with the Technical Work Place

Teachers in technical programs must be well-prepared to teach students both applied and theoretical skills. They must engage in regular academic activities to update content knowledge and remain current with technological development. As a response to such needs, educational institutions should:

- employ secondary school teachers associated with pre-technician education programs who have recent work experience related to their teaching areas and at least baccalaureate degrees in appropriate mathematics, science, engineering, or technology fields. All prospective teachers of technicians should also have relevant preservice training in pedagogy, particularly in providing applied instruction in mathematics, science, and engineering.
- provide effective exposure to teachers in secondary school technical programs to the technical work place (see Faculty Section, fifth recommendation).
- encourage secondary school technology, science, and mathematics teachers to take technical courses at two-year colleges.

Professional Societies and Government Agencies Should Facilitate Effective Assessment

Standards offer guidance to assessment procedures that provide feedback to students and teachers and guarantee quality of courses and programs. Thus, professional associations and government agencies should ensure that:

- standards (e.g., NCTM and NRC Standards) are developed and adopted to provide for all students to master a core set of competencies for mathematics, science, communications, social studies, and technological literacy.
- standards include the SCANS (U.S. Department of Labor 1991) work place competencies of managing resources; using, evaluating, and communicating information; dealing interpersonally with others; and using systems and technology.
- assessments are developed to enable students to demonstrate their mastery of the core set of competencies and the SCANS work place competencies.

Schools Should Incorporate Technology Education into Students' Early Years

Fundamental knowledge of technology and its effects on people, the environment, and culture is important for all citizens, including technicians. Starting in the early grades and continuing to early secondary school, schools should provide technology education:

- as a common subject in the school curriculum for all students. This education must involve both "knowledge and know-how" in conducting technological work. For greatest impact, contextual learning should be provided through concrete experiences that offer active ways of leading to and reinforcing mathematics and science concepts. Technology education should emphasize design, problem solving, and decision making involving human values, material resources, and technological systems and processes.
- to connect student learning across the curriculum in mathematics, science, communications, social studies, and other subjects with an organized set of concepts, processes, applications, and systems drawn from modern technology.

Professional Societies, NSF, and Other Government Agencies Should Support Development of Standards and Educational Materials

Teacher Enhancement Activities for Technology Education Should Be Supported

To provide a better foundation both for future employment in technical jobs and for life in a technological society, professional societies. the National Science Foundation, and other government agencies should:

- support development of common standards for technology education for implementation in mathematics, science, and technology education courses.
- support materials development and teacher enhancement activities which implement technology education standards in a variety of disciplines.

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National Council of Teachers of Mathematics. 1989. *Curriculum and Evaluation Standards for School Mathematics.* Reston, VA: National Council of Teachers of Mathematics.

U.S. Department of Labor. 1991. *What Work Requires of Schools.* Washington, DC: U.S. Government Printing Office.

(Only printed reports and documents referenced in this report are listed here.)

SELECTED PRECONFERENCE PAPERS

For the workshop, 12 papers, or specific compilations of information, provided a base for discussion. Three of these papers are included in this document because they represent broad statements on technician education: the Barley paper on what technicians do; the Wolf paper on the history of technician education; and the Chapman paper on professional society roles in technician education.

The other papers were on specific models of technician education. Abstracts are included below. Copies of all papers can be obtained from:

Kenneth Chapman
American Chemical Society
1155 Sixteenth Street, NW
Washington, DC 20036
(202) 872-8734

E. Peter Benzing,
What Can Be Learned from the German Apprenticeship System to Improve Skilled Worker Training in the United States?

Some features of the German Dual System model may be applicable to education in the United States.

Jan Berntson,
Imaging Technician Development Program

A comprehensive, post-associate degree, corporate training program has been developed for carefully selected new-hire technicians.

Ruth Ann Cade,
Expanding the Student Pipeline in Science, Engineering, and Technician Education

Enrichment programs are needed to raise the probability of success for women and minorities who have only recently been aggressively recruited for technical work.

Paul Dickinson and Richard Fosse,
Partnership for Environmental Technology Education

This partnership directs its attention to preparing environmental technicians in two-year colleges for both clean-up and prevention.

David Hata,
Training Technicians On-site

A two-year college presents an associate degree technician program on-site for the mutual benefit of students, the employer, and the college.

Diane Jernigan,
Tech Prep Articulation Agreement

A Tech Prep planning model that starts with the development of an applied science foundation at a vocational high school and that involves a two-year college and local industry has been implemented in Memphis.

National Research Council,
Excerpts from National Science Education Standards: An Enhanced Sampler

The status of the NRC Science Education Standards project as of early Spring 1993 was provided.

Theodore Towns,
The Bidwell Model for Technical Education of Adults

With attention to their individual qualifications, adult students become competent technicians through an intensive industry-sponsored program at the Bidwell Training Center.

U.S. Department of Education,
Voluntary Industry Standards

Twenty-two projects funded by the U.S. Departments of Education and Labor have started developing voluntary industry standards to describe what employers expect new-hire employees to bring to their jobs.

WHAT DO TECHNICIANS DO? (ABRIDGED)

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Draft in Circulation

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INTRODUCTION

Common sense notions about technician education sometimes prove misleading. For instance, the educational and policy literature routinely portrays technicians as a "junior professionals" whose work requires a less rigorous, more "applied" version of the formal knowledge of a professional specialty. If the image of a junior professional" is inaccurate, it may lead educators to develop curricula that are, at best, irrelevant and, at worse, a barrier to entry.

In 1991 researchers associated with the Program on Technology and Work at Cornell's School of Industrial and Labor Relations embarked on a five-year study to gather detailed information on technicians' work. To date, we have completed investigations of emergency medical technicians (Nelsen and Barley 1993), science technicians (Barley and Bechky 1993), medical technologists (Scarselletta 1992), radiological technologists (Barley 1990), and scientific liaisons in the European Space Agency (Zabusky 1993). Studies of microcomputer support specialists, engineering technicians, and programmers are under way. We are about to launch studies of technical sales, software engineering, automobile repair, and technicians on factory floors.

Some preliminary observations suggest that conceptualizing technicians as "junior professionals" misrepresents the technician's role through two unwarranted connotations: (1) that technicians serve professionals as functionaries, and (2) that the professional's knowledge subsumes that of the technician. We have found instead that the division of labor between technicians and professionals is usually more collaborative (horizontal) than hierarchical (vertical) and that members of the two types of occupations command substantively different knowledge and skill. Further, many technicians work in contexts that are not tied to the activities of a profession.

OBSERVATIONS

The Technician's Role

Overseeing an Empirical Interface: Most technicians work on or with reputedly complex technologies or techniques. Most also work at the empirical interface between a larger production process and the materials on which the process depends. The technician's task at the empirical interface involves two complementary processes: transformation and caretaking.

Technicians employ technologies and techniques to transform aspects of the material world into symbolic representations that can be used for other purposes. Technicians are also responsible for taking care of the physical entities they oversee.

Figure I depicts the technician's activity at an empirical interface. Transformation and caretaking represent the common epistemic core of a technician's job. The technician's social role, however, varies according to how the epistemic core is articulated within a divisic of labor. Based on our research and the research of others, we submit that technician's work is of at least two general types:

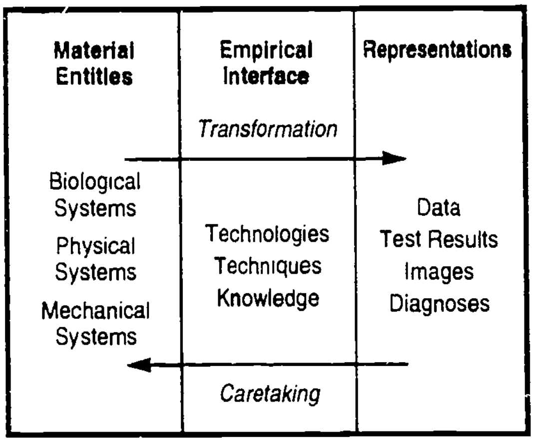

Figure 1:
The Technician's Work at the Empirical Interface: The Epistemic Core

(1) buffers (Figure 2) and (2) brokers (Figure 3). Technicians may buffer other occupations from contact with the empirical phenomena over which the latter are reputed to have mastery. These technicians are usually positioned near the beginning of a serially interdependent, occupational division of labor such that the technician's "output" serves as "input" for the work of an occupation classed as a profession. Thus, technicians link a world of symbols, information, or theory to its empirical referents. Since science technicians operate lab equipment, conduct experiments, and generate data, it is they, rather than scientists, who usually preside over science's encounters with the physical world.

Because the technicians and professionals speak much the same language, buffers usually transmit the representations they create directly to the professional. The professional then employs the technicians' representations in his or her own work.

Membership in a common speech community affects the technician's work as well. Technicians who serve as buffers usually draw on or appropriate the professionals' theories, plans, diagnoses, or designs for their work at the empirical interface. The central dynamic of the production process (which moves from left to right in Figure 2) is one of translation. The technicians who serve as brokers usually work in an organizational division of labor. Others do not depend on specific products of the technician's work. Instead the technicians are responsible for creating general conditions necessary for the work of others. Technicians of this sort, typically oversee some aspect of the technical infrastructure on which a production system rests.

The epistemic core of the second type of occupation is identical to the first. To manage a technological infrastructure, a technician must create symbolic representations of the state of the technology and then maintain or alter the technology based on the representations. However, the technician's position in the production system differs from that of a buffer. Brokers must assess the users' needs and then develop systems that meet those needs via their caretaking function; also, they must educate users about the system's functioning, features and limitations. Restatement and assessment therefore require brokers to engage in considerable translation and speak the language of both the technical and user communities.

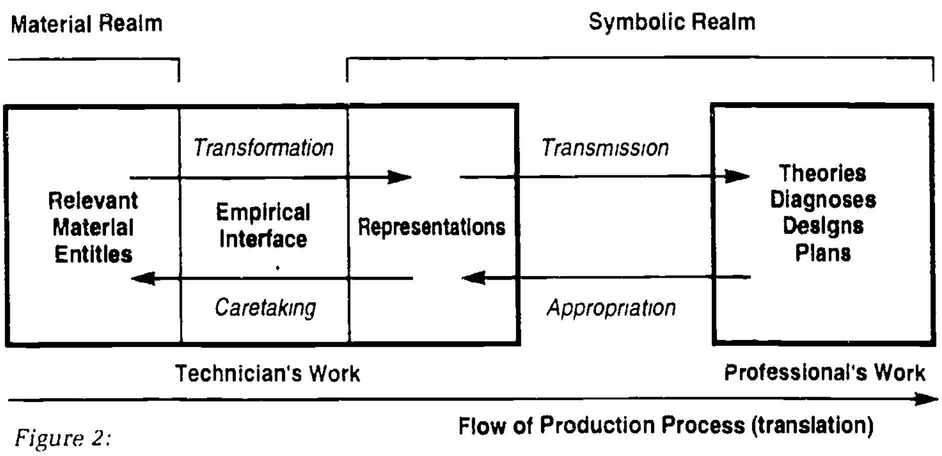

Figure 2:
Technicians as Buffers

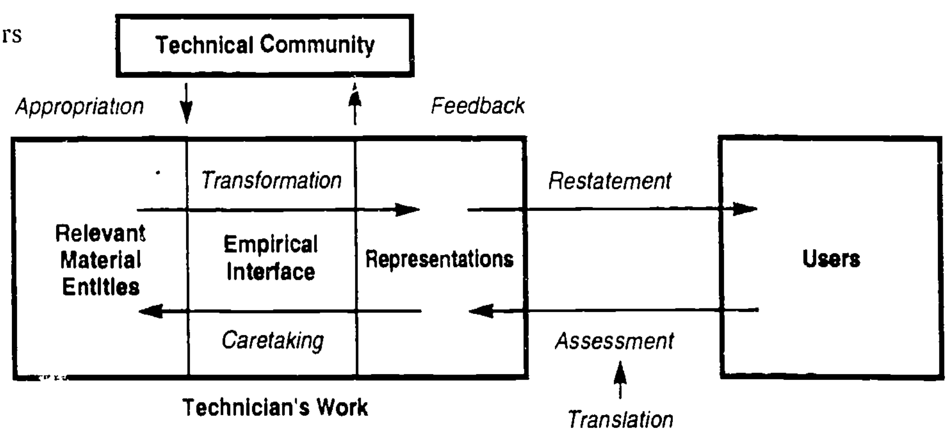

Figure 3: Technicians as Brokers

THE NATURE OF TECHNICIANS' KNOWLEDGE AND SKILL

Formal knowledge:
Contrary to the rhetoric that calls for more formal knowledge and credentials, we have found that the perceived importance of credentials contrasts sharply with the experience and opinions of technicians themselves. Barley and Bechky (1993) report that among of the university-based science technicians they studied, holding rank constant, a quarter possessed at least a master's degree but another quarter had no more than a high school diploma. Studies suggest that between 20 and 30 percent of all engineers in the United States lack a bachelor's degree in engineering and many have no more than a high school diploma (Zussman, 1985). Preliminary evidence suggests that many engineering technicians also lack advanced degrees. Barley and Zahusky (in progress) found that 50 percent of the microcomputer technicians and in-house programmers they studied have no formal technical training.

Perhaps more troublesome for advocates of credentialling is the fact that technicians with technical degrees also claim they use little of what they learned in school. In fact, we have yet to encounter a technician willing to testify to the importance of the content he or she learned in school. Technicians often claim that they think more "rigorously" or logically" about problems because of their education (Zussman 1985). When solving problems, technicians also occasionally employ heuristics and other bits of knowledge that can be traced to courses in technical subjects (Barley and Bechky 1993). The technician's devaluing of formal education is therefore best interpreted as a sign that they subscribe to a theory of learning that differs from that of most educators. Educators often portray courses in formal theory as a necessary platform for understanding the details of practice. Technicians believe the converse: that practice provides the platform necessary for making sense of theory.

Regardless of occupation, all technicians appear to value experience and practical understanding over formal knowledge. In fact, in our studies the only technicians who have made positive claims about their schooling were those whose training involved hands-on practice.

Contextual Knowledge:
Technicians universally value experience more highly than formal training. "Experience" for most technicians serves as a shorthand for contextual knowledge. Technicians argue that although contextual knowledge is required for successful practice, training programs provide few opportunities to acquire it. Technicians are particularly critical of the educational establishment's tendency to elevate theoretical over contextual knowledge. Almost all technicians claim that they had to acquire contextual knowledge on-the-job. Most employers do not orchestrate the training of new technicians; nor do they usually assign mentors to the newly hired. Instead, technicians appear to gain contextual knowledge by solving problems, by informal coaching, and perhaps most importantly by listening to "war stories" that encode lessons learned by colleagues (Orr, forthcoming). Face-to-face contacts are most pervasive. Technicians not only discuss problems and discoveries with their immediate colleagues, they are usually linked to technicians at other sites who can serve as informal consultants. Technicians therefore serve as repositories of contextual knowledge that is disseminated orally through networks. Vendors of equipment and supplies also function as crucial conduits of information. Some occupations, such a medical and radiological technology are sufficiently well organized to have their own journals.

Although, by definition, the precise content of contextual knowledge varies from occupation to occupation, broad commonalities exist. Most important is the ability to make sense of subtle differences in the appearance of materials and the behavior of techniques or instruments. Accomplished technicians see signs and codes where novices, and even professionals, seen no information at all. For example, bench talk in science laboratories routinely revolves around the relevance of colors, shapes, patterns, sounds, and smells (Barley and Bechky 1993).

Contextual knowledge encompasses an encyclopedia of heuristic or rules-of-thumb. Members of every technical occupation we have studied routinely recite heuristics to themselves and each other during their work. In fact, we have begun to wonder if talking to oneself is not actually critical for effective technical problem solving.

Technician as cutpoint: Because technicians serve as buffers and brokers, only they are positioned to develop a contextual understanding of materials and technologies. It is therefore the technicians' contextual knowledge rather than their formal knowledge that represents their substantive expertise. To the degree that contextual knowledge is necessary for the smooth functioning of a production system, the technician becomes a cutpoint for the entire system: Remove the technician and the production system collapses.

In every technical setting we studied we found clear evidence that technicians are vital precisely because their contextual understanding is pivotal. Even scientists admit that without technicians lab work would stop because scientists do not possess the contextual knowledge necessary for empirical activities. Further evidence for the pivotal importance of the technician's knowledge can be found in those instances where labs attempt to duplicate each other's work. It is usually necessary for technicians from the second lab to train technicians from the first (Cambrosio and Keating 1988).

Under certain conditions, microcomputer technicians also become cutpoints in a production system, especially when computers are networked. In fact, the use of outside technicians and computer consultants actually increases the odds of a malfunction.

IMPLICATIONS FOR POLICY

The foregoing observations challenge the prevalent image of a technician as a "junior professional" because they suggest that technicians are not mere adjuncts to an existing occupation. Instead, technicians are members of unique occupations with their own bodies of knowledge. Because this knowledge is largely contextual and because contextual knowledge is learned in situ, the technician's knowledge is not a subset of the knowledge commanded by another occupation. Furthermore, although technicians may have status incommensurate with their importance, it is not because they serve as functionaries in a vertical division of labor (Barley 1991; Barley and Bechky 1993). If accurate, these observations suggest at least four potential policy implications.

First, effective educational programs for training technicians must impart contextual knowledge of a technical domain. If one takes the technician's perspective seriously, hands-on experience must become integral to the education of the technical labor force. Apprenticeships and internships are ways of providing such experience. However, neither should be viewed as an adjunct to classroom instruction. Instead, classroom instruction might more appropriately be viewed as an adjunct to apprenticeship. If formal knowledge becomes relevant for technicians only in the context of practice, then it behooves educators to design curricula that tailor formal instruction to the exigencies of practice rather than the reverse. Apprenticeships and other hands-on experiences will not be maximally effective if approached as elaborate demonstrations to support theoretical points.

Second, practicing technicians must be involved in designing training programs. Unless educators and policy makers are themselves technicians (which, of course, most are not), they will be ignorant of the contextual knowledge that technicians require. Our observations imply that persons ignorant of the demands of practice do not usually design adequate training. Although an educator's knowledge of pedagogical tactics is useful for structuring the delivery of knowledge, it is important to recognize that the educator's expertise does not encompass the content of technical work. The same is true of professionals with whom some technicians interact. Policy makers must therefore be particularly alert not to confuse knowledge relevant for one occupation with knowledge relevant for another. Recognizing that technicians are themselves experts in the content of their work will lessen the risk of designing irrelevant curricula.

Third, conceptions of technical education must be broadened to include translation competency. Because technicians serve as buffers and brokers in a division of labor, a significant component of their work requires an ability to translate across the boundaries of social worlds. The skill is particularly crucial for technicians who work as brokers. Brokers must be able to assess the needs of users and to articulate technical issues in a language that laypersons can understand. Not only are general communication skills required but so is the ability to think of one's work and the work of others in systemic terms. The notion of translation is also useful for re-examining the role that formal theory plays in the education of technicians. Historically, technicians have been taught scientific, technical, or medical theory under the presumption that such knowledge provides a background crucial for the epistemic core of the technician' s work. Although this perspective has merit, it may be that theoretical knowledge is most useful for enabling technicians to communicate effectively with the professionals with whom they interact. This possibility casts a different light on the relevance of formal knowledge and, by extension, the way in which such knowledge is taught.

Finally, since technical knowledge changes so rapidly, technical work demands continual learning and access to new information. Since relevant technical knowledge is usually bound to the particulars of a problem, crucial information is difficult to systematize. For this reason, technical knowledge is generally spread informally and often orally through a community or network of practitioners. Policy makers should therefore direct resources to the development of tools for the timely exchange of information and the development of communities of practice. In particular, funds could be used to develop and maintain on-line databases indexed by terms that technicians use when solving problems. Resources might also be spent to facilitate the formation of the guild-like organizations that have proven so effective in spreading knowledge of techniques among craftspersons and professionals. Such approaches would recognize that from a policy perspective the community-of-practice is potentially a more relevant unit of analysis than the individual practitioner.

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EDUCATION FOR ENGINEERING AND INDUSTRIAL TECHNICIANS IN THE REINVESTMENT ECONOMY

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THE EVOLUTION OF TECHNICIAN EDUCATION FOR INDUSTRY

Applied wasn't the stylish thing to be in the post-sputnik years nor through the era of the arms race. Though leading-edge science and technology flourished, its reduction to nondefense endeavors slipped away because other producer countries reduced the time-to-market for new products. Now, as the U.S. seeks to revitalize its civilian industry, large numbers of technicians having the scientific background to understand the new technologies need to be deployed in manufacturing, maintenance and product support. These requirements will have a profound effect upon technician education.

THE TWO-YEAR ENGINEERING TECHNOLOGY ASSOCIATE DEGREE

Engineering technicians were a post-World War II phenomenon. The Technical Institute Committee of the Engineers Council for Professional Development (ECPD), now called the Accreditation Board for Engineering and Technology (ABET), formed to develop the criteria and procedures for the accreditation of two-year programs for technicians. Activities began in 1946 with seven programs at three technical institutes (ABET 1990). With the surge of the community college movement in the late 1960's, the Technical Institute Subcommittee went on to become the accrediting body for all associate degree programs in the field of engineering technology.

Two-year engineering technician programs produced personnel at a level that everyone agreed was needed. Technicians had a clear employee classification in which they could be recognized in pay and stature for their education beyond high school. The earnings differential divided by the sum of the direct cost of education and the small forfeited income for the short time in school, made it one of the best educational investments possible.

BIFURCATION OF ENGINEERING

The launching of Sputnik by the Soviets in October of 1957 shocked engineering education into adopting the recommendations of the ASEE Committee on Evaluation of Engineering Education from 1952 to 1955, which became known as the *Grinter Report* (ASEE 1955).

The Committee's objective was to provide a dual choice for each student of either a scientific or a more pragmatic orientation of his program of engineering (Grinter 1984). The Grinter Report bifurcated engineering into *engineering science* and *applied engineering*. Under the name of engineering science, schools were encouraged to go further into the mathematical analyses that were beginning to flourish with the arrival of the digital computer. Others, taking the name of *applied engineering*, were to remain in the realms of design, construction, and manufacturing.

What in hindsight seems to be cold war hysteria, virtually all engineering programs were converted to engineering science and none to applied engineering. My 1980 study of nine representative public and private mechanical engineering programs across the country shows that the number of credits that could be earned in laboratories using machine or welding shops reduced from 6.1% to 0.1% of the mechanical engineering curriculum during the period from 1955 to 1975. The number of credits earned through studio laboratories (engineering drawing, descriptive geometry, kinematics, and machine design labs) reduced from 14.4% to 5.8%. Meanwhile, the number of credits in engineering analysis grew from 2.9% to 14.7% (Wolf 1980). Programs were simply changed in content, though not in title, to engineering science.

THE TECHNICIAN/ TECHNOLOGIST SYMBIOSIS

It was conjectured that more two-year technicians might be trained instead to satisfy the need for the applied engineers. In 1959 the ASEE formed a distinguished committee with Jim McGraw, of the University of Dayton as the Chairman, to evaluate the associate degree product. *The Characteristics of Excellence in Engineering Technology Education* was produced in 1962 (ASEE 1962). This very prestigious report became the basis of the ECPD criteria for engineering technology and influenced the development of many associate degree programs. There are now 450 accredited associate degree programs at 166 institutions in the U.S.

Though two-year programs produced excellent technicians, they were not a substitute for applied engineers for the obvious reason that one couldn't accomplish in a two-year program what had formerly been done in four-years. But, more acutely, a technician program was seen by many parents and potential students as an educational dead-end. Thus, it was difficult to recruit the kind of student necessary to complete a rigorous associate degree technician program. So, amid much contention the bachelor degree programs in engineering technology were born. A subcommittee of the Engineering Technology Council of the ASEE, formed in 1964 to study the concept of four-year technologist programs. *The McCallick Report* was released in 1965 (McCallick 1966). ECPD accredited the first four-year ET program in 1967.

Employers then as now ignored the title of technologist. Some technologists were called technicians. But most, to the consternation of many engineering schools, were called engineers. Nevertheless, the number of four-year ET programs has grown to 312 bachelor degree programs accredited by ABET at 112 different institutions today (ABET 1990).

The four-year technology programs worked on both counts. A supply of applied engineers was created, while a trail for the upward mobility of technicians was blazed. Though only about twenty percent of the technicians would go on to further education immediately after graduation, half of all those who received associate degrees would eventually find their way to the bachelor program, usually on a part-time basis (Wolf 1977). By dispelling the dead-end image, the four-year programs attracted far more qualified students as freshmen into technician education programs than those same programs drew off from the two-year technician graduating class.

The bifurcation of engineering in the U.S. did not follow the process imagined in the Grinter Report; but the effect, if not the titles, did come into being. In 1983, Grinter wrote, "Nevertheless, the natural forces of student desire and employer need have brought about a nearly complete solution through the development of four-year BET curricula" (Grinter 1994).

LINGERING ISSUES IN ENGINEERING TECHNICIAN EDUCATION

Insufficiency of Numbers

The U.S. produces about 50,000 associate degree engineering technicians per year, most from unaccredited programs. American colleges and universities produce about 100,000 engineers per year. On the assertion that there should be at least two technicians for each engineer, we need four time as many technician graduates as there are now.

Programs
The 54 excellent colleges of technology in Japan (one in every prefecture) are nationally supported. In the U.S., associate degree technician courses must compete for existence with less expensive nontechnical courses within locally supported comprehensive institutions.

Variances in Quality
Most two-year technology programs are not ABET accredited and lack the math and science basis to become so. There seems to be an over-reliance upon local advisory committees at a time when technician programs need to meet national and international standards.

Currency of Subject Matter
Technology progresses at an accelerating pace. Yet, there is no systematic process for continually upgrading subject matter.

Preparation of Faculty
The overwhelming need in preparing technology faculty is related to the content of the instruction. Yet, those few schools of education that still purport to train technology faculty have removed the technological content, preferring to offer certification programs which deal only with teaching methods. Since content drives method in the teaching of technicians, there is no effective training for technology faulty.

Continuing Professional Development
Technicians in other industrialized countries have more well defined career paths with greater stature.

Peer Identification
Technicians do not have peer group support in the form of professional associations. They are out there alone, with few role models, professional publications, or networks.

Continuing Education
The explosion of technology makes the need for continuing education among technicians acute. Technicians desire not only degree conversion programs, but also focused continuing education containing the right information and reaching the right individuals when those individuals are ready for it.

Elitism
Elitism does indeed exist and is the greatest enemy of applied education. I have seen numerous examples of it during my 30 years of technology teaching and administration. It exists among counselors, administrators, senior officers, engineering societies, industrial supervisors and human resource administrators, foundations and funding agencies and especially among fellow students and nontechnical faulty. Elitism dissuades young people who would benefit from applied education, demoralizes technology teachers, produces a dumping ground, is blind to opportunities, and drains off philosophical and financial support. Those who would divert funds from technical education to something that is more respectable use the very word, *technician*, in the pejorative sense.

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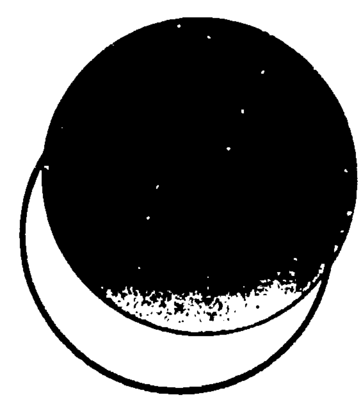

ONE SOCIETY'S RESPONSE TO TECHNICIAN NEEDS

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ABSTRACT

Addressing technician needs has not been a high priority role for discipline-oriented associations. Since 1963, the American Chemical Society has steadily increased its response to the professional and educational needs of technicians who require chemistry knowledge and skills in the performance of their duties.

Today, technicians have a Division in the Society; manage the affairs of that Division; plan and present technical programs for both national and regional ACS meetings; and work on behalf of technicians through a local chapter arrangement in more than 20 areas of the country.

On an irregular basis, the Conference on Two-Year College Chemistry devotes one of its four meetings per year to chemical technology education. The Society uses an approval program parallel to that used for baccalaureate programs to signify the quality of chemical technology curricula. The textbook series, *Modern Chemical Technology* (ACS 1970), produced in the early 1970s with NSF funding, now appears in its third edition. The Society recently was awarded a U.S. Department of Education grant to develop Voluntary Industry Standards for technicians. Using the findings presented in the SCANS report (U.S. Department of Labor 1991) and information provided through a variety of other sources, it is also exploring a new applied science program to fit the technical specialty slot in high school-level Tech Prep programs.

THE DIVISION OF CHEMICAL TECHNICIANS

This Division (probationary until August 1994 by ACS rules) was created by a group of technicians who gained experience with ACS procedures through an earlier unofficial organization supported by the ACS Committee on Technician Activities. Technicians managed the process of developing support for the proposed division and created the structure to meet all the requirements imposed by ACS on Division operation. The Division members are actively recruiting new members to ensure that more than 250 ACS members are signed on by August 1994. That number has been nearly reached more than a year early and total Division membership is about 1,000.

The stated goals of the Division include enhancing professional status, providing continuing education, informing others about careers, and providing a network among peers. This effort received further support at a recent ACS Board of Directors retreat where industry leaders advised that ACS should do more to recognize chemical technicians as professionals.

In the five years since its inception, the ACS National Technician-of-the-Year Award has been presented to one white female, two Hispanic males, and two white males. The slate of Division officers presented by the Nominating Committee in 1993 consisted entirely of females. The technicians whose work has lead to the current level of technician activity in the Society have been truly diverse by both race and gender. Thus, technician activities in the Society show an appropriate diversity without any special efforts having been made.

TECHNICIAN EDUCATION TODAY

The Society's Technician Resources/Education program is located in the Education Division. While the program title is new for 1993, technician educational interests have received continuing attention since 1963. In recent years, the activity level has increased steadily.

At present, the Society provides opportunities for technician educators to meet together and exchange perspectives, compare programs, and tell war stories. In the past year, one national meeting and one regional meeting (joint with the Chemical Institute of Canada) have had major chemical technician education programming.

ACS began approving B.S. programs in chemistry in 1936. That service was extended to chemical technology programs in 1991; however, quality guidelines have been issued since 1967.

The stigma associated with technician education combined with chemistry have made recruitment for A.A.S. chemical technology programs very difficult. Small student numbers have discouraged textbook development. However, the Society made available *Modern Chemical Technology* in 1972 with NSF support and has helped guide the text through two subsequent editions. Two handbooks for chemical technicians and a couple of other textbooks prepared for technicians also are now available. That is a very small literature resource for the technicians who are a key support group for an area of the economy responsible for 18% of the gross national product.

To provide a better foundation for curriculum redesign and instructional materials development, the Society is now undertaking the development of Voluntary Industry Standards with U.S. Department of Education support. ACS will work closely with the Chemical Manufacturers Association and the International Chemical Workers Union in this endeavor. Preliminary results are expected to be released in 1994.

To respond to a variety of problems that affect the wide range of technicians whose work depends on chemistry, biology, and earth sciences, the Society is studying a course currently referred to as SciTeKS, for Science Technology: Knowledge and Skills. This course is proposed as an applied, contextual, and authentic approach for science in the technical specialty block within the engineering/industrial cluster of the Tech Prep framework of school reform. The targeted students for SciTeKS typically would receive only limited preparation for long-term careers through general or vocational education programs. An example module for SciTeKS is presently under development.

SCITEKS

SciTeKS incorporates the competencies identified in the SCANS Report and pedagogical features proven in recently developed science and technology curricula. SciTeKS courses would emphasize: analyzing problems; developing problem-solving skills; teamwork; working safely; recognizing and correcting deficiencies in skills and knowledge; and developing a sound foundation of scientific knowledge and laboratory skills.

The sample module now being developed requires the class to function as a quality control team for an aspirin manufacturing unit that is exploring changes in the synthesis procedure. In addition to learning new organic and analytical chemistry, students will learn about batch processing, good manufacturing practices, good laboratory practices, FDA regulations, environmental responsibility, and economic factors that affect aspirin production.

SciTeKS will place much different demands on students than is now typical of chemistry and biology courses. As their experience grows, students will take an increasing responsibility for determining their own knowledge and skills inadequacies. They will become responsible for decision-making and their decisions will determine class operation. The pedagogical changes will develop teamwork skills, emphasize planning and operations functions, require greater use of information resources, and demonstrate the interaction of other systems with the practices of science.

SciTeKS will demand that teachers be joined with scientists, engineers, and technicians from the nearby community in the instructional process. In addition to special training for all SciTeKS teachers, a supportive national network should provide quick access to information and advice. Teachers will need a continuing, close association with science efforts in their local community.

THE TEAM

ACS relies heavily on volunteers. Fortunately, technicians have always been an important volunteer group for Society committees dealing with technician affairs. Today, technicians are sought for membership on ACS committees outside the technician arena. However, technicians need support from employers just as do their scientist and engineer counterparts if they are to participate in organizational activities. And, that participation can be local as well as national.

In the practice of science and engineering, technicians are accepted as critical components. They are just as critical as components of the organizations of the technical communities in which they serve.

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SUMMARY COMMENTS

CRITICAL ISSUES IN SCIENCE AND ENGINEERING TECHNICIAN EDUCATION INVITATIONAL WORKSHOP

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July 23, 1993

These summary comments reflect my thoughts about ideas presented in both the papers and the presentations. Please excuse me for not crediting individual authors or presenters. Several ideas and themes were recurring.

First, let me share some facts and findings:

- The United States remains a world leader in the production of scientists and engineers and in developing new technologies.
- Other countries out-compete us in turning these new technologies to economic advantage.
- Several study panels have warned us that we hav: lost our national competitiveness because we have neglected our nation's workforce.
- Unless we take corrective action, we will doom our people to an unprecedented low standard of living, and our nation's national security will be threatened.
- The current level of worker training in the United States is inadequate to raise the productivity and quality to the extent needed to improve our competitive position in world markets.
- Secretaries Riley and Reich are advocating that the skills, adaptability, creativity, and knowledge of the American worker must be the foundation for restoring competitiveness.
- Both workforce preparation prior to employment and workforce training after employment need to be strengthened.
- There is a lack of connection between the skills needed in the workforce and the skills imparted through education and training.
- Only 25% of American youth graduate from college, leaving a 75% neglected majority.
- Eighty percent of the workforce of the year 2000 is currently on the job.
- American businesses spend $45 billion annually on workforce training.
  - Ninety-five percent of this expenditure is concentrated in large companies of 500 or more employees.
  - Eighty-three percent of the $45 billion is spent on inservice training for executives, managers, and sales staff, leaving only 17% for front-line workers.
- Small companies account for 60% of the nation's jobs and 80% of all new jobs in the last ten years.
- The United States is the only industrialized nation without a formal system for the development and dissemination of workforce skill standards.

The following information is provided in the Scientific and Advanced Technology Act of 1992;

- Improvement of workforce productivity and our international economic position depend upon the strengthening of our educational efforts in science, math, and technology, especially at the associate degree level. (This is a refreshing recognition of the importance of education to economic development.)

- Shortages of scientifically and technically trained workers are best addressed by collaboration among the nation's associate-degree-granting institutions and private industry to produce skilled advanced technicians.

- NSF shall award grants for:
  - Development of model instructional programs. (We suggested also the dissemination of model curricula.)
  - Professional development of faculty.
  - Establishment of public-private partnerships.
  - Acquisition of state-of-the-art equipment.
  - Dissemination of instructional materials.
  - Funding up to 10 National Centers for Scientific and Technical Education.

There is a need to more clearly define the term technician.

- Technicians are not junior scientists and engineers. Different skills are required, the skills of application rather than theoretical skills.

- However, the differences between technicians and scientists or engineers are not well understood.

- The nature of technician's work is changing as work is being pushed down to lower levels because of company downsizing and streamlining.

- In the language of the Scientific and Advanced Technology Act, advanced technology includes modernization, miniaturization, integration, and computerization of electronic, hydraulic, pneumatic, laser, nuclear, chemical, telecommunication, fiber optic, robotic, and other technological applications to enhance productivity improvements in manufacturing, communication, transportation, commercial, and similar economic and national security activities.

- From the workshop materials: For this workshop, technician will apply to those whose education and work activities require using mathematics at least through algebra as well as applying scientific principles and design or laboratory skills to science and engineering applications. Collegiate education to at least an associate of applied science degree, or its equivalent acquired through some corporate or military programs, is required.

- Complicating our definition is the fact that some technicians have come up through the ranks in companies without formal education.

- The current economy has given industry a good supply of bachelor's degree scientists and engineers to hire as technicians, further complicating the definition.

- There is a need to improve the status or prestige level of technicians.

- "Technician" has a negative connotation among some.

- Some companies have even deleted this job title and substituted other labels such as research associate. However, even this term is not well defined and can be used to designate a scientist or an engineer at another company.

- A common definition, national standards, program accreditation, and technician certification should improve the status of the profession.

- Professional societies can enhance the status of the profession by creating divisions for technicians. Some already have.

- Industry should assess the effects of the trend to hire temporary or adjunct scientists, engineers, and technicians on the status of the profession and on long-term productivity.

- Strategies must be developed to reduce and eliminate cultural barriers to the technician profession and to job satisfaction.

- People from all groups should be acknowledged for their contributions.

- Technician careers and their importance to the nation can be marketed using television, radio, brochures, and posters. Current technicians are the best sales people. Marketing efforts should show an openness to women and minorities.

- High school counselors and teachers need information about technician careers.

- We need data about technicians.
  - How many are there in the current workforce?
  - In what industries are they found?
  - How many are in large versus small companies?
  - What are the projected needs? (Supply and demand)
  - What are the demographics? (age, gender, ethnicity, work location)

- We need to define competencies for technicians.
  - It is necessary to characterize the knowledge, skills, and abilities of entry level technicians.
  - What training should be: generic versus industry specific versus company specific? Proprietary knowledge would have to be provided by companies.
  - Competencies and characteristics mentioned at the workshop include: critical thinking skills, problem solving skills, analytical skills, teamwork skills, knowledge of safety measures, technical skills (science and lab), computational skills, oral and written communication skills, work ethic, aptitude, interest, enthusiasm, adaptability, self-motivation, organizational skills, flexibility, and ability to follow through.
  - After generic and industry specific skills are learned, companies must take it from there.

- Secretaries Reich and Riley are recommending voluntary national skills standards.
- Skills standards should include generic competencies and industry (not company) specific skills for broad clusters of major occupations.
- World class skills standards should be jointly developed by industry, labor (technicians themselves), professional societies, and academia. All of these are stakeholders and should be part of the partnerships or alliances formed.
- Academia must listen to (and involve) industry in establishing skills standards. In the past, industry representatives have felt left out.
- Small companies should be included in the establishment of skills standards. Their needs for skills and competencies may be different from those of larger companies.
- Federal agencies or professional societies should bring stakeholders together to develop skills standards.
- Once these competencies and skills standards are defined, they must be accepted and honored by industry. Job descriptions should require certification. Industry will need to resist the temptation to employ people who don't have the certification when the demand returns.

- Components and characteristics of education and training for technicians discussed by workshop groups include the following:
  - National skills standards can be used to evaluate the content of academic programs and serve as a basis for program accreditation.
  - National examination boards; made up of representatives of all stakeholder groups (industry, labor (working technicians who know the job requirements best), community colleges, universities, secondary schools, and professional societies; will provide a path to be certified.
  - Tech Prep and other innovative programs should help to improve the substance and image of vocational training in secondary schools. There has been too much emphasis on the college preparation curriculum, ignoring the needs of 75% of the high school students.
  - We must overcome the biases of status conscious parents and high school professionals who try to encourage every student to go to a four-year college or university.

- We must provide for the needs of nontraditional and returning students. Child care, tutoring, advising, financial aid, remedial work, career counseling, and job placement services must be provided. Underrepresented and nontraditional students often have a limited sense of their career options.
- Education and training must involve hands on experiences.
- Technicians need practical experience and contextual knowledge rather than theoretical knowledge. However, they must have a sound basic foundation of knowledge.
- Apprenticeships, internships, or cooperative education experiences need to be a core part of the education.
- Mentors from industry (employed technicians and supervisors) should be provided for students.
- Mentors should be trained in how to be mentors. (Some community colleges already offer courses in this subject.)
- Programs must encourage collaborative or cooperative rather than competitive learning.
- Programs must be developed for the continual learning and updating of technicians.

- Technology programs should be placed near areas of employment for the following reasons:
  - Need for internships.
  - Need for advisory committees.
  - Need for mentors.
  - Need for access to state-of-the-art equipment owned by industry.
  - Need for guest lecturers or adjunct faculty from industry.
  - Apparent lack of mobility of graduates.

- Industry must release staff to serve as guest lecturers, mentors, and as members of program advisory committees.

- All stakeholders must be involved in curriculum development and review.

- Community colleges and four-year institutions must articulate courses for ease of transfer to benefit the technicians who wish to obtain an advanced degree. Bridge programs may need to be developed.

- Industry must provide a career path and a career ladder for technicians.

- Faculty should have previous industrial experience.

- High school and community college faculty should periodically spend some time in industry. This applies both to teachers of technicians and to teachers of basic sciences. Schools, colleges, and companies will have to develop programs to allow this experience.

- Professional societies can create opportunities for professional development, networking, and recognition for career advancement.

- Community colleges and companies can make use of new instructional technologies for teaching, including interactive video and distance learning.

- People who move from industry to high school and community college teaching need to learn pedagogical skills. Credential requirements must be relaxed to allow this to happen.

- Teachers of technicians need to be recognized as professionals.

- Non-monitory rewards of teaching must be emphasized. Schools and colleges cannot compete with industry for salaries.

- The curriculum should reflect skills and competency standards and should include general, technical, and industry specific components. The general component should have a strong emphasis on math, science, and communication.

- The ideal educational program should permit multiple exits and opportunities for re-entry.

- Educational programs must provide for part-time students.

- Programs should be evaluated periodically to maintain accreditation.

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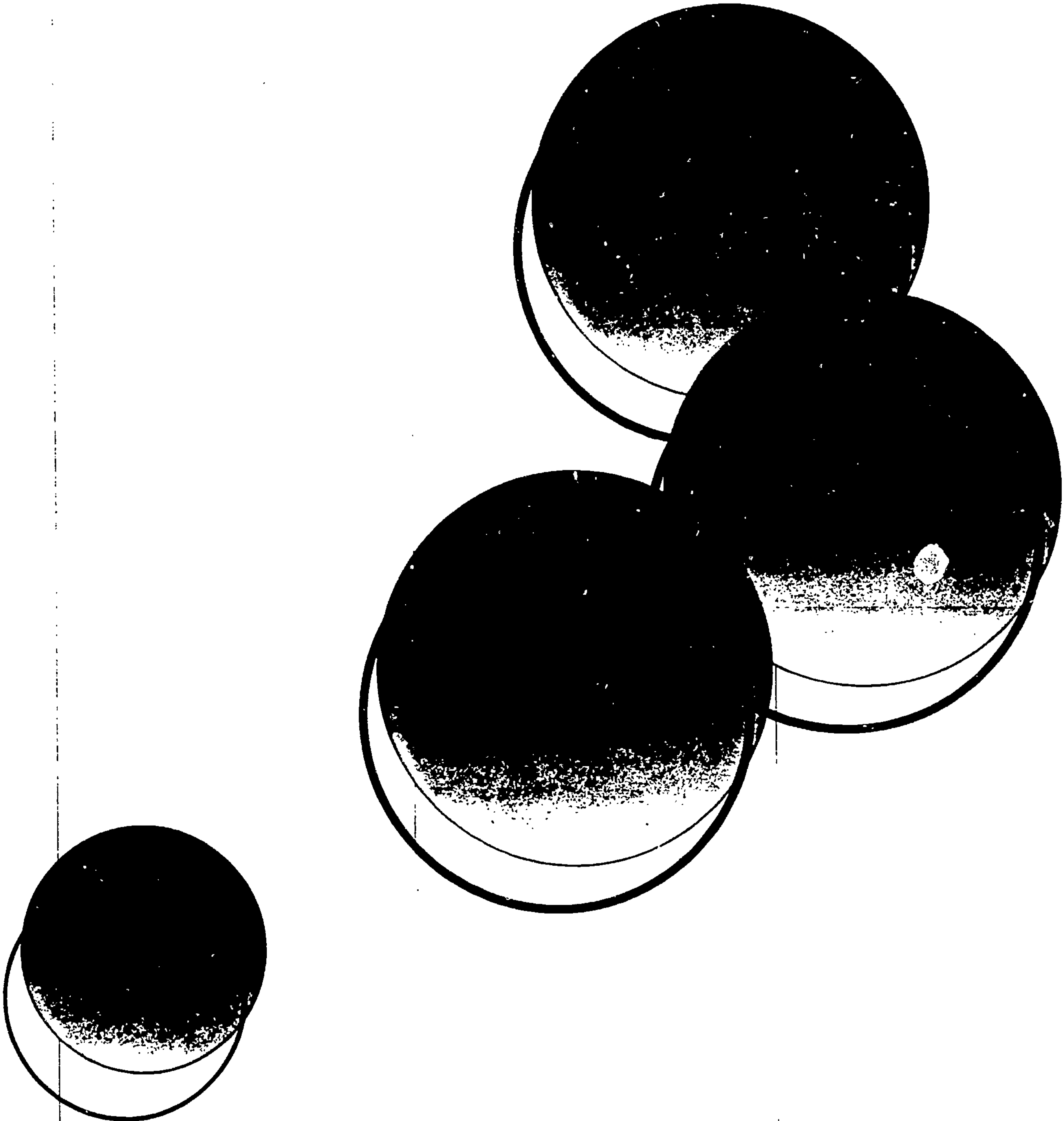

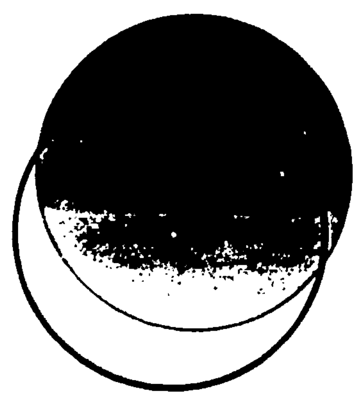

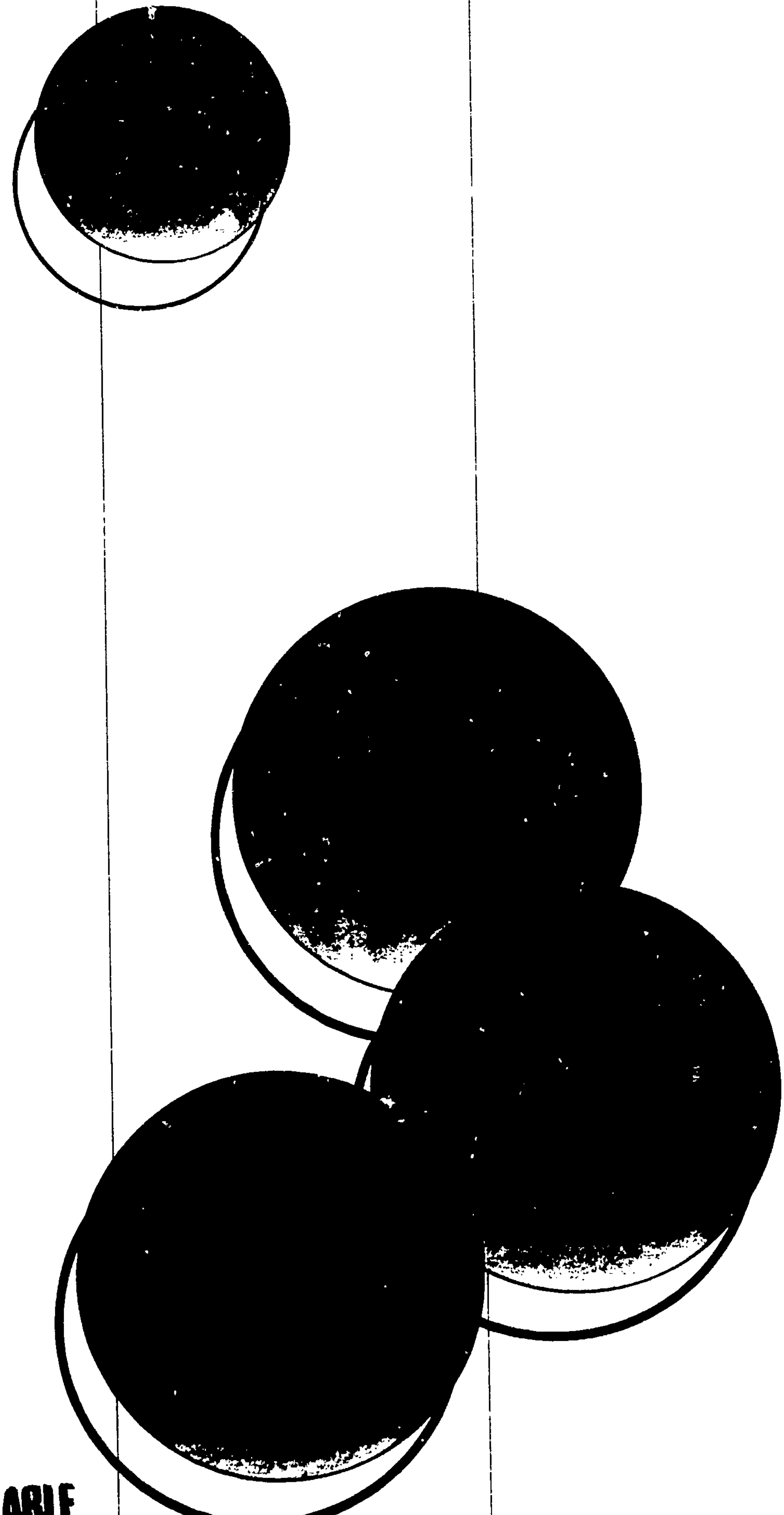

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